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TRANSACTIONS

OF THE

American Ceramic Society

VOLUME VIII.

Containing Papers and Discussions Read at the Meeting Held at Philadelphia, Pennsylvania, Feb. 5th, 6th and 7th, 1906, with Some Other Contributions.

Published by the Society
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This Society is not, as an organization, responsible for the statements of facts or opinions expressed in its papers and discussions.

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1906

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PRESS OF FRED J. HEER
COLUMBUS, OHIO
1906

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Skeele, H. B., Chicago, Ill.	Ludowici Roofing Tile Company.
Smith, Amedee M., Portland, Oregon.	Western Clay Manufacturing Co.
Smith, Perry A., New Brighton, Pa.	Sec'y A. F. Smith Company.
Speir, Oswald, 87 W. 34th St., New York.	

Staley, Homer Francis, B. A., Uniontown, Pa.	Chemist, The McCrum-Howell Co.
Stamm, John, East Liverpool, Ohio.	General Manager National China Company.
Steele, W. N., West Winfield, Pa.	Supt. Sewer Pipe Works.
Stanbery, George A., Zanesville, Ohio.	American Encaustic Tile Company, Ltd.
Stephani, W. J., Philadelphia, Pa.	Supt. and Ceramist, O. W. Ketcham Terra Cotta Company.
Stevenson Wm. G., East Liverpool, Ohio.	Sec'y and Gen. Mgr., Ohio Silica Company.
Stull, Ray T, E. M., Mt. Savage, Md.	With Mt. Savage Enameled Brick Company.
Stowe, Charles B., Cleveland, Ohio.	The Stowe-Fuller Company.
Taylor, William Watts, Cincinnati, Ohio.	President, Rookwood Pottery Co.
Thomas, Chauncey Rapelje, Amherst, Mass.	Ceramic Student.
Thomas, David C., Wellsville, Ohio.	United States Pottery Company.
Thrall, Charles U., Tottenville, S. I., N. Y.	Supt., Atlantic Terra Cotta Co.
Tone, Frank J., Niagara Falls, N .Y.	Works Mgr., Carborundum Co.
Townsend, Everett, Morrisville, Pa.	National Tile Company.
Trommer, Carl E., 100 William St., New York.	Roessler & Hasslacher, Chemical Company.
Volz, William J., St. Louis, Mo.	Supt., Evans & Howard Fire Brick Company.
Wagner, Fritz, Chicago, Ill.	Northwestern Terra Cotta Co.
Walcott, Benjamin O., Indianapolis, Ind.	Pres., Indianapolis Terra Cotta Co.
Walker, John A., Jersey City, N. J.	Joseph Dixon Crucible Company.
Wells, Harry B., Matawan, N. J.	Supt., The New Jersey Company, Brick Manufacturers.
Whitehead, C. Louis, Trenton, N. J.	Providential Tile Works.

Whittaker, John L.,
Trenton, N. J.
Works Mgr., Lenox Incorporated.

Will, Otto W.,
Perth Amboy, N. J.
Supt., Color Mfg. Dept., Roessler & Hasslacher Chemical Co.

Williams, Ira A., B. S.,
Ames, Iowa.
Geological Department Iowa State College.

Wolf, George,
502 Perry Ave., Peoria, Ill.

Worcester, Wolsey Garnet,
Columbus, Ohio.

Yates, Alfred,
Drummond, Pa.
Shawmut Paving Brick Works.

Young, George F.,
Zanesville, Ohio.
Mgr., Roseville Pottery Co.

ANNUAL REPORT OF THE BOARD OF TRUSTEES.

PHILADELPHIA, PA., February 5, 1906.

Members and Associates, American Ceramic Society.

GENTLEMEN: — We have the honor to report to you for your information the following facts connected with the Society's business for the year beginning February 1, 1905, and ending February 1, 1906.

INCORPORATION OF THE SOCIETY.

According to a resolution adopted at Birmingham, it was decided that the Society should become an incorporated body, and the Council was ordered to proceed with this business at its early convenience.

The Ohio law prescribes that a majority of the incorporators must be citizens of Ohio, and not less than five in number. It was the intention to have the Council act as the incorporating body, but as only three of its members were from Ohio, it was necessary to increase the number of incorporators to nine, consisting of the Council and two others, the latter to be citizens of Ohio. This made five a majority of the body and made this majority consist of citizens of Ohio as required by law. Messrs. Bleininger and Richardson were requested by the Council to join with them as the incorporators, which they did.

This body met May 12, and proceeded to organize the American Ceramic Society under this new charter. A record of the proceedings has been duly incorporated into the Records of the Society, and has been examined by an attorney and found according to law.

Legal opinion has also been secured to the effect that the original American Ceramic Society has by this act ceased to exist and that the new organization, a body constituted under the same rules, and governed by the same officers, has superseded it. The property accumulated under the old organization, which had no legal status, has passed under the control of the new organization, under a proper legal status. The members of the old organization, in paying dues and participating in the meetings of the Society as now constituted, thereby assume the duties of membership in the new organization.

PUBLICATION OF VOLUME VII.

Under the resolution adopted by the Council and accepted by the Society at Birmingham, it was decided to change the publication of the Transactions from an annual to a quarterly journal, and at the same time appoint an editor at a salary of $200 per annum to take care of the work. The Society adopted the recommendations of the Council. The

Council then elected Professor A. V. Bleininger as editor, and he assumed the duties of the position at once. He has published the Transactions, Vol. VII, in three parts instead of four. This was caused by a miscalculation as to the amount of matter which would be available. It was found that so large a portion of the matter to be published had been consumed in the first two issues, that what was left would be insufficient to make two more good issues. For reasons of economy, the Board of Trustees therefore, decided to publish but one additional part. The first issue appeared April 20, the second July 10, and the third November 21.

This method of publication has not given the results hoped for. The issues have not been brought out promptly, and the journalistic feature has not been developed as it was hoped it might be. No single person has been to blame. The situation has shown that a journal of the desired excellence cannot be brought out under the arrangements thus far provided. The editor, and the Secretary unite in recommending that we go back to the old plan of an annual volume, if money cannot be secured to employ a considerable part of the time of an able man who will serve as editor to the periodical. It cannot be carried successfully as an addition to the daily labors of a busy and hard-worked teacher or practical man. At the same time, if only one volume per year is to be gotten out, the editor and secretary both think that the cost for editorial work can and should be cut down — perhaps to $100 instead of $200.

There remains in the hands of the Secretary about 250 copies of Parts I, II, and III of Vol. VII. It is recommended that these be rebound in a new paper cover to agree with the former publications of the Society before they be placed on sale. The cost of so doing will be small, about 15 cents a copy, and will certainly give better satisfaction to future purchasers.

THE BRANNER BIBLIOGRAPHY.

The members of the Society will remember that two years ago, Professor H. A. Wheeler announced that overtures had been made to him by Dr. John C. Branner of the Leland Stanford, Jr. University, to the effect that he would present to the Ceramic Society, outright, the copy for a new and much enlarged edition of his "Bibliography of Clays and the Ceramic Arts," which appeared first as a Bulletin of the United States Geological Survey in 1896, if the Society would publish it. This matter was acted upon by the Council and Society and the offer accepted. Nothing definite was heard of the matter for a year, when Dr. Branner answered a communication from the Secretary stating that he was going abroad, and on his return in July, 1905, he expected to hand over the copy for the Bibliography according to the offer made and accepted a year earlier.

In August, 1905, Dr. Branner sent the copy for the Volume. The Board of Trustees and Society had acted finally on the matter at the summer meeting in Chicago, instructing the Secretary to proceed with the work as soon as the copy became available. Therefore, he began at once on the task.

Bids were secured in the East and in Columbus. The bid of the F. J. Heer Publishing Company of Columbus was the lowest and the contract was awarded them. The printing has progressed well, considering the distance to which proof had to be sent. The book is now all in type, two-thirds of it is paged, part of it already printed, and it will be ready for sale by April 1, 1906.

The book is bound in light blue, the Society's color, with the Society's seal on the cover, and the Society's name on the back as publisher. A dummy copy is here for inspection. In the judgment of the Secretary, the standing of the Society will be greatly advanced among scholars and scientists by the bringing of this Volume out as a part of our publications.

It was decided at the sixth annual meeting that the Society could not afford to give a copy of this book, together with the Transactions for the ordinary dues paid by members and associates. It was then decided that the book should be sold to members of the Society, on the same basis as to others. The Society, therefore, has no claim on its members to buy the book, except by appeal to their loyalty to an enterprise which the Society has undertaken, and which bids fair to greatly add to its professional and scientific renown. The Board of Trustees hopes to sell at least 200 copies to members of the Society, in the next 60 days.

Accordingly, a subscription list is being circulated at this time, on which all who agree to buy one or more copies of the Volume are enrolled, and payment in advance is requested. It is the intention to reach the absent members by mail.

The funds required to meet the cost of publishing this Volume will be realized by this advance sale in part. The deficiency will be met by a loan, for which the Board of Trustees will be the surety. The funds arising from the sale of the Volume will be kept separate, and used to cut down this debt, until it is removed, after which all future revenue will be covered into the treasury of the Society for its general revenues. It is thought that the book will pay its cost in a year, and will leave about one-half of the issue to be sold for profit. One thousand copies are being printed. Libraries, china collectors and Ceramists the world over will undoubtedly be eager to obtain it.

Before closing, it is only proper to inform the Society of the highly generous manner in which Dr. Branner has borne himself. It would appear that he had dealt most liberally with the Society in donating his manuscript to us, without recourse, with full permission for us to make what revenue from it we are able, for the Society's benefit.

But, in a recent communication, he has voluntarily offered to pay all costs for extras incurred in printing. These extras, as all who deal with printers know, are frequently a considerable per cent of the total cost, and are always irritating, because they cannot be foreseen and allowed for. In this instance, the extras cover the insertion of 350 new titles, which have been collected since the original matter on which bids were asked was handed in, and the cost of changes in copy due to editing, etc. The Society in being relieved of this cost will be able to present a book of high quality to the public, at a very moderate cost to the purchaser and a fair profit to itself.

THE SUMMER MEETING.

The members of the Society met at Chicago for a summer meeting on July 17, 18 and 19, and spent three days together most enjoyably and profitably. The minutes of the meeting appear in the records, in full. The policy of the Society in maintaining a summer meeting seems justified to those who attend these meetings, but it is a source of regret that the number attending is so small a proportion of our whole number. This matter is recommended to the Society for discussion.

THE PUBLICATIONS.

The following table shows the present status of our publications:—

Vol. I		292
Vol. II		280
Vol. III		175 (?)
Vol. IV		255
Vol. V		231
Vol. VI		244
Vol. VII, Part I	297	
Vol. VII, Part II	281	281
Vol. VII, Part III	285	
Manual		185
		1,943

These volumes constitute the chief property of the Society and they are being looked after in a careful manner. They are kept insured in the sum of $2,000.00. Their value, at an average of $3.00 each, which represents about what they net the Society from sales of all sorts, is, $5,829.00.

SALE OF TRANSACTIONS.

During the year, the Secretary and the Treasurer have by mutual consent changed the method of handling the sales. The Treasurer formerly kept all volumes for sale, filled all orders, conducted all corespond-

ence concerning sales and collections and in fact looked after the merchandising end of the Society's affairs. These duties have gradually become so onerous that the Treasurer found himself unable to carry the work, in connection with increasing responsibilities in his business. Adjustment being necessary, the Secretary took over all of the above work, except the actual banking of the Society's funds and paying of bills. The Secretary has made remittances and statements to the Treasurer from time to time. The centralizing of the correspondence concerning dues, sales, and all business matters in one place has proved of benefit to the Society, but has also made the work of the Secretary's office much heavier.

In order to meet this situation temporarily, the Secretary has charged the insignificant sum of two dollars ($2.50) and fifty cents per month for clerk-hire. This cannot be carried on permanently on this basis, however, as the Society's business has now become a very considerable matter, and is constantly increasing. The Secretary recommends that the Secretary be authorized to employ an assistant, competent to keep the books and conduct business correspondence, and that the same be paid for on the basis of 25 cents per hour for the actual time consumed. This would leave the Secretary free from the ordinary business work, except to oversee it, and thus be able to devote what time he can to correspondence and editorial work concerning the technical side. It is believed that the Society's affairs have now reached a volume which justifies putting them on a business basis.

GROWTH IN MEMBERSHIP.

The growth in membership has been gratifying. There has been but one ballot taken since the last annual meeting. The changes in our rolls since the last statement stand as follows:

Brought forward February 1, 1905—		
Honorary members	1	
Full members, resident.....	29	
Full members, foreign.....	1	
Associate members, resident..	119	
Associate members, foreign...	16	
	166	 166
Accessions.		
By election to full membership.....	5	
By election to associate membership.....	29	
	34	 34

Losses.

Associates promoted	5		
Associates resigned	4		
Associates dropped for non-payment of dues	6		
	15	15	
Net gain		19	19
Total present strength			185

The number of outstanding applications at this time brings the number well above the 200 mark. The Society is to be congratulated on this healthful growth.

Respectfully submitted,
THE BOARD OF TRUSTEES,
by Edward Orton, Jr.,
Secretary.

TREASURER'S REPORT.

CINCINNATI, OHIO, February 1, 1906.

To the American Ceramic Society.

GENTLEMEN: — I have the honor to submit to you my report as Treasurer of the Society for the year 1905-06:

RECEIPTS.

Brought Forward from Preceding Year —		
Regular balance	$576.45	
Old accounts received	66.50	
Dues paid in advance	54.67	
	$697.62	$697.62
Received as Dues, 1905-06 —		
29 Members @ $5.00	$145.00	
5 Initiation fees @ $10.00	50.00	
130 Associates @ $4.00	520.00	
27 Initiation fees @ $5.00	135.00	
1 Foreign associate @ $3.90	3.90	
1 Foreign associate @ $3.89	3.89	
Partial payment on account	1.00	
	$858.79	$858.79
Received from Sales of Publications —		
5 Volume 1	$8.70	
6 Volume 2	16.40	
5 Volume 3	10.20	
7 Volume 4	17.20	
8 Volume 5	29.20	
21 Volume 6	67.60	
5 Volume 7	15.40	
14 Complete sets	163.60	
35 Manuals	34.20	
45 Segers Collected Writings	344.70	
	$707.20	$707.20
Total receipts		$2,263.61

DISBURSEMENTS.

Stenographic Report —		
Mrs. B. G. Kalb	$247.25	$247.25
Printing —		
Hann & Adair	$810.96	
Heintzmann & Co	7.80	
Chemical Publishing Co	274.51	$1,093.27
Engraving and Drawing —		
Bucher Engraving Co	$62.80	
Prof. T. E. French	46.65	
C. B. Harrop	8.40	
	$117.85	$117.25
Editor's Salary —		
Prof. A. V. Bleininger	$150.00	$150.00
Expenses of Secretary's Office —		
Stenographer	$26.00	
Postage	19.75	
Incorporation papers	8.50	
Insurance of publications	21.00	
Sundries	3.97	
	$79.22	$79.22
Expenses of Treasurer's Office —		
Stenographer	$5.00	
Incorporation expense	5.00	
Postage and general	17.59	
	$27.59	$27.59
Total expenses		$1,715.18
Balance on hand to next year		$548.43

Respectfully submitted,

STANLEY G. BURT, *Treasurer.*

We have examined the above report, and verified it by comparison with the vouchers and with the certified check for the balance on hand and find it correct in all particulars.

A. F. HOTTINGER,
ELLSWORTH OGDEN,
HERFORD HOPE,
Auditing Committee.

RULES.

OBJECTS.

The objects of the American Ceramic Society are to promote the arts and sciences connected with Ceramics by means of meetings for social intercourse, for the reading and discussion of professional papers, and for the publication of professional literature.

MEMBERSHIP.

The Society shall consist of Honorary Members, Members and Associates.

Honorary Members must be persons of acknowledged professional eminence, and shall not exceed five in number.

Members shall be persons competent to fill responsible positions in Ceramics and have suitable qualifications.

Associates shall include persons interested in Ceramics and the allied arts.

Honorary Members shall be proposed by at least five members, approved by the Board of Trustees, and receive at least 90 per cent. of the votes cast by letter ballot at the annual meeting.

Members and Associates shall be proposed by at least three Members or Associates, approved by the Board of Trustees, and receive at least 75 per cent. of the votes cast by letter ballot. A candidate for admission must make application on a form prepared by the Board of Trustees which shall contain a written statement of his age, professional experience, and that he will, if elected, conform to the laws, rules, and requirements of the Society.

All Honorary Members, Members and Associates shall be equally entitled to the privileges of membership, except that only Members shall be entitled to hold office and to vote. Applicants for a change in grade of membership shall conform to the requirements of a new applicant.

Any person can be stricken from the membership of the Society on the request of five or more members, on the recommendation of a majority of the Board of Trustees, if he fails to resign on the advice of the Board of Trustees. Such person, however, shall first be notified of the charges against him, and be given a reasonable time to appear before the Board of Trustees, or present written defense, before final action is taken by the Board of Trustees.

DUES.

Honorary Members shall be exempt from all dues.

The initiation fee of Members shall be ten dollars, and of Asso-

ciates five dollars, which if not paid within six months after election, will render the election void.

The Annual dues for Members shall be fixed by the Board of Trustees, but shall not exceed five dollars per year.

The annual dues for Associates will be fixed by the Board of Trustees, but shall not exceed four dollars per year.

Any Member or Associate in arrears for over one year may be suspended from membership by the Board of Trustees until such arrears are paid.

OFFICERS.

The affairs of the Society shall be managed by the Board of Trustees, consisting of a President, Vice President, Secretary, Treasurer, and three Trustees, who shall be elected from the members at the annual meeting, and hold office until the adjournment of the meeting at which their successors are elected.

The President, Vice President, Secretary and Treasurer shall be elected for one year, and the Trustees for three years; and no President, Vice President, or Trustee shall be eligible for immediate re-election to the same office.

The duties of all officers shall be such as usually appertain to their offices, or may be delegated to them by the Board of Trustees or the Society; and the Board of Trustees may at its discretion require bonds to be furnished by the Treasurer.

Vacancies in any office shall be filled by appointment by the Board of Trustees, but the new incumbent shall not thereby be rendered ineligible to re-election at the next annual meeting to the same office. On the failure of any officer to execute his duties within a reasonable time, the Board of Trustees, after duly warning such officer, may declare the office vacant, and appoint a new incumbent.

A majority of the Board of Trustees shall constitute a quorum; but the Board of Trustees shall be permitted to carry on such business as it may desire by letter.

ELECTIONS.

At the annual meeting, a nominating committee of five Members, not officers of the Society, shall be appointed, and this committee shall send the names of the nominees to the Secretary at least 60 days before the annual meeting, who shall immediately forward the same to the Members. Any other five members may also present the names of any candidates to the Secretary, provided it is done at least 30 days before the annual meeting. The names of all candidates, provided their assent has been obtained, shall be placed on the ballot without distinction as to nomination by the regular or an independent nominating committee, which shall be mailed to every member, not in arrears, at least 20 days before the annual meeting. The ballot shall be enclosed in an inner blank envelope, and the outer envelope shall be endorsed by the voter,

and mailed to the Secretary for collection. The blank envelopes shall be opened by three Scrutineers appointed by the Chair at the annual meeting, who will report the result of the election. A plurality of the votes cast shall elect.

MEETINGS.

The annual meetings shall take place on the first Monday in February, at such place as the Board of Trustees may decide, at which time reports shall be made by the Board of Trustees, Treasurer, and Scrutineers of election, and the accounts of the Treasurer audited by a committee of three appointed by the Chair.

Other meetings may be held at such times and places during the year as the Board of Trustees may decide, but at least 20 days' notice shall be given of such meetings.

Seven members shall constitute a quorum at any regular meeting, and a majority shall rule, except where otherwise specified.

The order of business at the annual meeting shall be:—

1. Reading of Minutes of last meeting.
2. Reports of the Board of Trustees and Treasurer of the Society.
3. Announcement of Election of Members.
4. Announcement of Election of Officers.
5. Appointment of Nominating Committee.
6. Old Business.
7. New Business.
8. Reading of Papers.

PUBLICATIONS.

The Board of Trustees shall act as a Publication Committee, and decide as to what to publish. The publications of the Society shall be sent to all Members and Associates not in arrears. The Secretary will furnish each author with reprints of his papers at cost price, provided due notice is given that reprints are desired.

The Society is not, as a body, responsible for the statements or opinions expressed in its publications.

PARLIAMENTARY STANDARD.

Roberts' "Rules or Order" shall be the parliamentary standard on all points not covered by these rules.

AMENDMENTS.

These rules may be amended at any regular meeting by a two-thirds vote of a letter ballot at the subsequent annual meeting, provided a written notice of such proposed change is sent to each member at least 30 days before said annual meeting. Said proposed amendments shall be printed on the ballot for officers and counted by the same Scrutineers.

PUBLICATIONS.

The publications of the Society are as follows:

	Description of Volume.	Price to Members.	Price to Others.
Vol. I.	Transactions for 1899, 110 pages, bound in paper,	$0.50	$4.00
Vol. II.	Transactions for 1900, 278 pages, bound in paper,	2.00	4.00
Vol. III.	Transactions for 1901, 230 pages, bound in paper,	1.00	4.00
Vol. IV.	Transactions for 1902, 300 pages, bound in paper,	1.50	4.00
Vol. V.	Transactions for 1903, 420 pages, bound in paper,	2.00	4.00
Vol. VI.	Transactions for 1904, 287 pages, bound in paper,	1 50	4.00
Vol. VII.	Transactions for 1905, 454 pages, bound in paper,	2.25	4.00
	Manual of Ceramic Calculation (contained in Vol. II as a part thereof,) 86 pages, bound in paper,	1.00	1.00
	The Collected Writings of Dr. Hermann August Seger, Volume I. Contains (A) Treatises of a general scientific nature, (B) Essays relating to Brick and Terra Cotta, Earthenware and Stoneware, and Refractory Wares. Pages, 552. Bound in cloth.	7.50	7.50
	The Collected Writings of Dr. Hermann August Seger, Volume II. Contains (B) Essays on Whiteware and Porcelain. (C) Travels, Letters and Polemics. (D) Uncompleted works, and extracts from the archives of the Royal Porcelain Factory. Pages, 605. Bound in Cloth,	7.50	7.50
	A Bibliography of Clays and the Ceramic Arts, by Dr. John C. Branner — 1906 — 451 pp., bound in cloth. Contains 6027 titles of works on Ceramic subjects,	2.00	2.00
	Cost of full set, not including manual.....	28.75	45.00

At the Cincinnati meeting, the Board of Trustees fixed a sliding scale of prices to apply to the sale of volumes of the Transactions, when the number unsold falls below 200 copies. As the copies become scarcer, prices will be increased to both members and others. The supply of four of the volumes has already fallen close to 200 copies, and is diminishing steadily, and will probably pass below this mark during the coming year. Members and Associates who do not yet own full sets are advised to procure them at once.

At the same meeting the following resolution was adopted:

Resolved, That the custom by which members and associates may obtain copies of the Transactions at reduced or so-called "member's rates," is intended only to enable each person to obtain one complete file of the transactions.

The necessity for this resolution arose from the expressed desire of a member to buy a copy of the transactions, with the intent to sell it to a friend for whom he wished to save the additional price charged to non-members. In accordance with the spirit of this resolution the Secretary will not supply more than one copy of a volume to a member at reduced rate, except when loss or destruction of a volume gives good cause for so doing.

Every member or associate receives one copy of the Transactions for each year for which he pays dues. He is entitled to purchase copies for the years antedating his connection with the Society at the costs indicated in the first column. All others can obtain copies at the prices listed in the second column by sending order, accompanied with check, to

EDWARD ORTON, JR., Secretary,
Columbus, Ohio.

PAPERS AND DISCUSSIONS.

ADDRESS OF THE RETIRING PRESIDENT.

W. D. GATES, Chicago, Ill.

The past history of this Association needs no comment from me. Its history is well written in its printed reports, and those reports now show more genuine, powerful research than can be gathered elsewhere in the English language on the subject of clay working. They show broad development, lofty advancement and a high standard working to the upbuilding of the art as an art, they show a getting away from and above and beyond the old petty secresy of hoarding and locking up of discoveries, as a miser hoards money, unused and profitless.

The toil, self-denial and generosity of our individual members has wrought out this result as nothing else could have done, and indeed, such a result could not have been attained without such sacrifice.

To a very unusual extent have our members participated in this work, in their free giving out of their knowledge, and in like measure as they have given, have they received in return. They themselves have grown in the doing of it. In addition they have the great satisfaction of seeing their beloved art grow until it has come to be a truly acknowledged art and a profession. Then, too, they have established their own place in history and when they themselves are gone, other generations will ponder their words and bless them.

All this is apparent from a glance at the published proceedings which now have a world-wide circulation, and which speak for themselves and tell their story wherever they go, to the English speaking world.

There are some things, however, which they do not and cannot tell. Outside of and beyond the formal papers and discussions, there is the strong item of personality. There is the social meeting together of one worker with another, of enthusiast with enthusiast, and the formation of such friendships as could be formed in no other man-

ner and in no other place. There is no written record to show of these many conferences and discussions, held two by two or in "Section Q," and there can possibly be no written record, as they are of such an impromptu character and so lack formality that it would be impossible to get them into print.

How often have we gone from these earnest talks, tearing ourselves away in the early hours of the morning, only leaving then that we might catch a little sleep, to be at it again early in the new day. And then we went scheming for new effort and experiment as soon as we returned to our factories, full of new ideas and inspirations gathered at these impromptu meetings.

Then too how grateful have we felt at the warm encouragement and help of our brothers, and how often, though going away conscious of our inability to repay them personally and in kind, still we felt desirous to help if not them, then some other to whom we might possibly be of service, and thereby, in some measure, contribute our part.

The midsummer meetings have largely to do with the social side of our gatherings; the going to the various plants with the resulting visiting together on the train and in the hotel lobbies furnish ideal opportunities for this purpose.

No one knows, and no one ever will know, what absolute money savings have resulted from just these meetings, and just these social conferences.

You are thinking of a line of experimental work and you happen to meet a brother who has worked it out and found its fallacies, and that little conference saves your time, energy and expense for something else. You have a trouble with body or glaze or burn that has nearly driven you crazy, and you have worried over it till you reason in a circle and make no headway. You talk it over with the right man and he, coming to it fresh and unfagged, is able to size it up judicially from your statement, and give you new and clear ideas that break the spell

and make you anxious to get back to the laboratory and go at it again with a new zeal that will bring success.

All these things we who have enjoyed these benefits know, and know well, but there are many still who should enjoy them who do not know. These men we want. We want the broad-minded ones, we want more of those who will glory in the advancement of the art they love and who will not hesitate to give to that end of their time and effort. And again I say that to those who give shall indeed be given abundantly and in no small measure.

Our art is not confined. There is still a wide field of production in other things. We must strive not only to make better wares, but to let people know their value and increase their use, and then too we can make other and new wares.

To a very great extent the clay worker takes only the trade that comes to him and works but little to extend the use of his wares. The very fact that this trade does come to him and that there is so much of it, shows much for the volume that would come did he but exploit his wares as those in other lines do.

Millions of acres of swamps have become fertile gardens because our people have made drain tiles; good tiles that have done the work as nothing else could have done it, that have strung great arteries and veins all over our country, carrying away malaria and disease and leaving fertility and production, health and plenty. Our sewer pipe men have made our homes healthy and our cities possible. Our brick men have made our cities and our streets safe and permanent. Our terra cotta men have made our office and business blocks and our homes beautiful and lasting. Our fire proofing men have made them safe, and our roofing tile men have shut out rain and storm and added beauty, yet all of us, to a very great extent, have taken just the business that came and exploited little.

We have to too great an extent devoted our energies to manufacturing better goods and lessening cost and

reducing price and neglected the very great advantage to be had by increasing the demand.

Strangely enough, the very class who could be most benefited by our organization have been the ones to hold themselves aloof.

The brick man, the drain tile man, the roofing tile man, the fire proofing man, the sewer pipe man and the terra cotta man have all participated to a large extent and they have been benefited by it, having made better ware and more profit from their participation. The white ware potter alone has been more chary, he of the ancient craft, he whose ware the faithful housewife cleanses three times a day, a thousand times a year, seventy thousand times, if she lives her allottment, and who contributes to him every time she drops a dish, he whose life is one long succession of dunts, crazes and shivers, stays away from the very place that would do him good, ease his troubles, lighten his cares and cause him to get an occasional night's rest.

But he will not stay away long; he is beginning to see the light; we want him and he is getting willing.

I am not a prophet and I know the past better than I know the future. Most of my obstructions appear to me after I have fallen down over them, but I see great things for the future of this Association and the coming advancement of our art. I see an era of progress. I see a period where, instead of making the same old thing at a loss, we will arrive at a point where we will either exploit it and increase the demand so that it will command a paying price, or we will go ahead and make some other thing that people do want and that they are willing to pay for, and I look to this Society, as the leading influence, to make American clay working hold a world wide reputation, and that right soon.

Personally, I confess, I have not contributed, except in small measure to the technical wealth of the Society. It has, however, not been that I did not want to do so: the spirit was willing but the head was weak. Then, too,

so much of my time was taken up with the financial problems connected with an ever recurring pay roll that my experimental work has largely been confined to that field. However, I am still willing and hopeful, to some day, contribute my mite toward the uplifting, dignifying and bettering of our art.

To this Association I owe some of the pleasantest memories I hold. To it I owe much of the little success I have achieved. To it I owe some of the best friends a man ever had, friends who were a joy to have and who joyed in helping, who liked giving better than receiving and whose strong personality, warm hearts and clear heads made them God-given treasures.

To this Association I owe the honor of presiding here, and while I cannot but feel that when you voted me in as President, your hearts got the better of your heads, still I like it and I like you for it.

I thank you sincerely for letting me be one of you, for the honors you have conferred on me and for the forbearance you have shown with my failing and inefficiency.

ADDRESS OF THE NEWLY ELECTED PRESIDENT.

W. D. RICHARDSON, Columbus, Ohio.

Returning from a trip to the Pacific Coast recently, I found upon my desk a communication from the American Ceramic Society announcing the report of the nominating committee. I was surprised and somewhat frightened to see my name at the head of the list of nominees. I had received no intimation that I was being considered for this high office, nor did I know the name of a single member of the nominating committee. This I do not consider strange or unusual. I know that no member of this Society would seek office, and I believe it is not customary to consult a member as to whether he will accept an office. There is no member who would not consider it an honor to be chosen an officer of the Society, and I am sure no one would shirk any task or responsibility that might be placed upon him.

For myself, I feel so greatly indebted to the Society for benefits that I have received from papers presented and discussions had at these meetings, as well as from association with its members, that I could not refuse to do anything in my power which might advance the interests of the Society.

That you have deemed me worthy the honor of the presidency, touches me deeply. My friends and fellow members, I thank you for this testimony of your esteem and confidence. No honor has ever come to me which has been so highly appreciated. I believe, however, that I owe this position not alone to your wish to reward me for active interest in this Society since its organization, but that your action is an expression of your desire to recognize the important industry with which I am connected and the work done by our brickmaker members in the formation of this Society and in the promotion of its objects. We want to have included in our membership all who are interested in the advancement of the clayworker's

art, be he producer of the beautiful art pottery or manufacturer of the more useful and homely common building or fire brick, drain tile, or sewer pipe. The brickmaker needs the American Ceramic Society, and the American Ceramic Society needs the brickmaker. I want to take this opportunity to say to the brickmakers of America, join the National Brick Manufacturers' Association and the American Ceramic Society. Identify yourselves with these movements for better things, for more exact knowledge, for technical education, for technical literature of our art, and for social intercourse with those engaged in like pursuits. Do you not feel that you have been hampered in your progress by inexact and limited knowledge? Then, avail yourselves of these means for increasing your intellectual resources.

Do you not feel that you should contribute something to make the world a little better for your having lived in it, something to the advancement of the art to which you have given the best years of your lives, something which may make it easier for your sons and successors to accomplish that which has cost you so much of time and money and even to do that which you have failed to accomplish? Many of you have opportunity and facility for observation and experiment not possessed by those with superior school advantages, and often the envy of the professor in his laboratory. Observe your processes accurately and systematically, and bring your records to these meetings. Thus you may not only help others, but you are almost certain thereby to extend the limits of your own knowledge. But even if you feel that you are not able to contribute anything for our information, give us the inspiration of your presence and the support of your influence. The money required for your membership is a small matter to you, but to the Society it means much. A larger income makes possible the publication of more literature pertaining to the technics of the manufacture of ceramic products. Moreover, an income such as the Society would have if even a majority of the brickmakers of the country

would lend their support by becoming members, would enable the organization to carry on a series of technical investigations which would prove of immense benefit and satisfaction to all of us and to those who may follow us, and incidentally, perhaps, make it possible for some worthy young man to pursue his studies at one of our ceramic schools.

These results can only be accomplished by association. Does not the sum of membership fees in the N. B. M. A. and the American Ceramic Society seem paltry beside the benefits to be derived? How can these facts be impressed upon the brickmakers and other clayworkers of the country to the end that our membership and income shall be increased to the extent it should be?

These words addressed to my fellow brickmakers are not to be taken as an indication that the Society is not growing. There has been steady increase in membership, and the large number present at this first session gives promise that our Eighth Annual Meeting will be the largest ever held. There is no question as to the permanency and increasing influence and usefulness of the American Ceramic Society. That is a well settled fact.

COST OF PRODUCTION OF COMMON AND PAVING BRICK AT CARNEGIE, PA.

BY

W. M. FICKES, Carnegie, Pa.

The simple and profitable art of brick-making, as viewed from the standpoint of the man engaged in some other business, furnishes an easy road to the rapid accumulation of wealth. If paper and pencil are called to his aid and the estimated profit of a plant of so many thousand per day is figured out, there is no room to doubt the ease of becoming wealthy. This method or, better, lack of method, is the main reason why so many brickyards are built, run a short time, shut down and are sold out under the hammer or are left to rust out.

The ease of this sort of profit-taking could be illustrated by several examples, but the following, taken from an old notebook of mine and made by me shortly after leaving college, are sufficient:

Cost of making 30M, common brick per day.

5 men,	clay bank	$7.50
1 "	pan feeder	1.75
1 "	pug-mill	1.50
1 "	machine	2.00
2 "	hackers	3.50
2 "	transfers	3.00
4 "	setters	8.00
3 "	burners	6.50
1 "	coal hauler	1.50
1 "	engineer	2.25
		$37.50 ÷ 30 M. = $1.25 per M.
Labor		$1.25
Coal		1.00
Oil		.05
Dynamite		.05
Other supplies		.10
Loading		.25
Interest on investment, etc.		.25
		$2.95

Soon after making this estimate, I built a plant and began to make brick. After one year's run on this plant, I found that our actual cost was over $5.00 per M. instead of $2.95. This had been in part due to poor machinery, but was enough to convince me of the fallacy of estimated profits. A careful study of our year's work convinced me that the difference arose from three principal causes:

1st. Interest on investment or depreciation of plant and value of clay used.

2nd. Non-productive labor, such as watchmen, foremen, burners and all others who are employed but not actually engaged in making brick.

3rd. Repairs and supplies.

In our particular case, the value of our real estate is greatly increased by the removal of the shale, as the latter lies high above the desired surface grade. The land after being stripped of its shale is just at the proper elevation above the railroad tracks for factory sites, and the increase in value due to this cause more than covers the value of the material used.

To cover the item of depreciation of plant, we decided to make a charge of $2,400 per year, and since then we have used this figure in determining our monthly costs.

The item of non-productive labor is the hardest to obtain, as it is dependent on all the various delays, breaks, holidays, etc., that interrupt the steady output of brick and cause the annual output to run under the estimated production.

After trying several ways to obtain some idea of the cost of repairs, I decided to use a monthly sheet, form II., on which the labor was divided daily and which also gave us a record of the material made and shipped and the cost of repairs and supplies. This form was in some respects exactly what we wanted and gave us valuable information regarding our non-productive labor. On the other hand, we found that the cost of the labor ran about constant for the production of our output, and it was decided to con-

dense this form and use some other method of determining the daily cost. To do this we adopted form I., supplemented by our kiln record, form III., and a repair and supply sheet, form IV.

The items on form I. are derived in the folluowing way:

1. Labor, taken from the weekly payrolls and covering all labor employed for any purpose.
2. Coal, from monthly bill and covering all fuel used.
3. Supplies and repairs, from form IV, division being made as shown in the example
4. Fixed charges covering depreciation, $200.00 per month.
5. Total, sum of 1, 2, 3 and 4.
6. The remaining items are determined from form III and our ledger, the only point being the proper division of cost when making both block and brick at the same time. Our previous experience had shown the block to cost ½ more than the brick, and our division was made on this basis.

A short review of form I. shows very clearly the importance of steady production and the way in which the non-productive labor increases the cost. A comparison of February (four days run) and April (every day) needs no further explanation, but it makes one wonder how he could fail to consider it in making up an estimate.

To obtain the cost of our repairs, we refer to our payrolls, on which we make weekly separation of the labor into that used for repair work and that used in producing brick, and to our supply sheet, form IV. Last year the labor bill for repairs amounted to $825.90. No attempt was made to divide this, as we found that one man might be employed on repairs on several machines during the day and to try and separate the day's work was unnecessary for our purpose.

Of the supplies, we made the following division from

the monthly sheets, form IV: Pans, $712.92; pug-mill, $144.39; brick-machine, $339.75; repress, $330.95; car improvement, $303.18, and material for new kiln, $212.02.

From the above items, it will be seen that our pan repairs are very heavy and in order to explain the cause of this and to make these figures of any value for comparison with any data that may be added to this from time to time, I will give a detailed description of our plant and equipment.

From the map of our plant, fig. 1, and a cross section of our clay bank, fig. 2, one can readily see that for a building or as a manufacturing site the property, as we purchased it, was of no value whatever, but after the construction of a cut-off branch of the P., C., C. & St. L. Ry. through our property (marked Scully Branch), the portion between the cut-off and the main line, if leveled down, would become of very much greater market value. With this in view we have been running for the last year on the 15 ft. of hard shale mixed with the stripping from the R. R. cut, but it has caused our costs to run much higher than the year before.

The upper strata, consisting of weathered shale and surface-clay, makes a very desirable and easily worked bank, and with the exception of the sandstone layers offers no especial difficulties and requires three men less to handle the same output.

The lower 15 feet of shale we are now working is of such a mixed character that a description of it is difficult. In a general way there are four materials present: a soft blue shale, a hard blue shale, a medium hard yellow shale, and a hard sandy layer. There is no regularity as to the proportion of each present, and the only way that I can give you an idea of this irregularity is to tell of a recent variation. On one side of a vertical seam or crack, we were working, beginning at bottom, 2 feet of hard blue shale, 6 inches of hard sandy rock, 3 feet of yellow shale, and the balance soft blue shale; on the other side we had 4 feet of soft blue shale, 2 feet of hard blue shale, 1 foot of

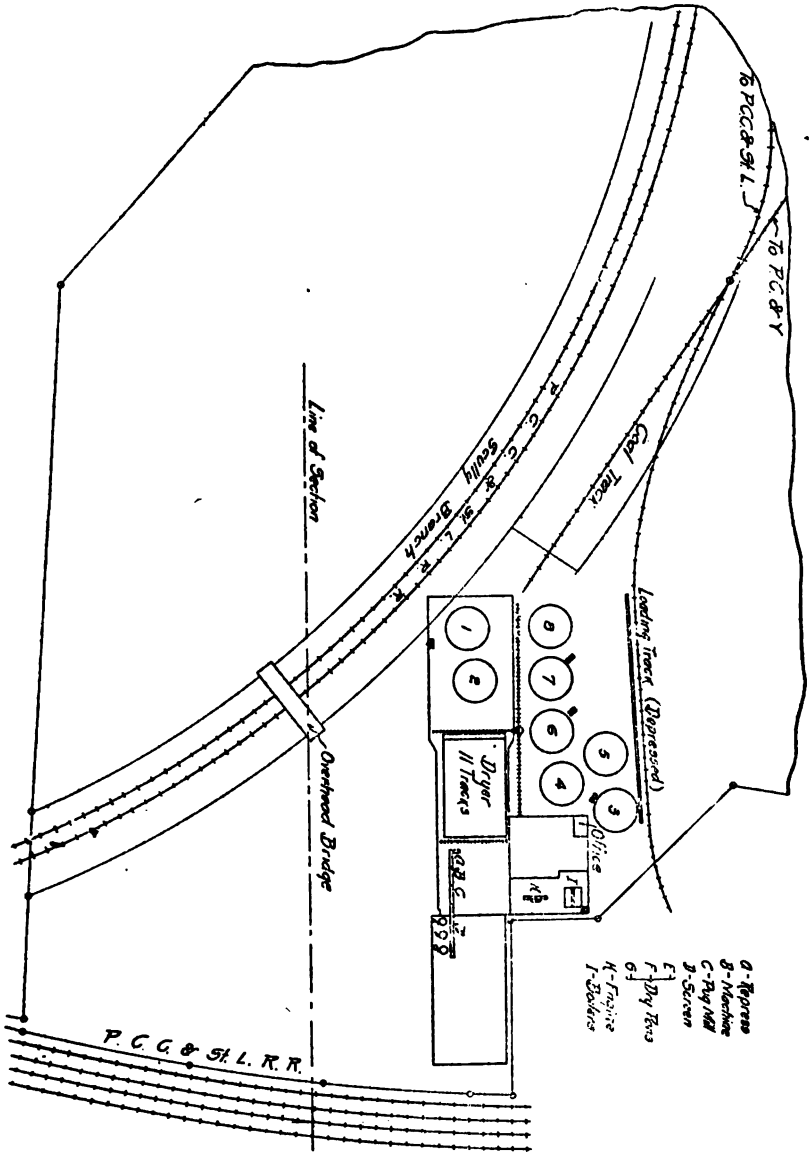


FIG 1 Lay-out of the Rosslyn Brick Co., Carnegie, Pa.

yellow shale, 6 feet of soft blue shale and 2 feet of hard blue shale, no hard sandy rock having been found.

The two blue shales are very similar, except in hardness, showing little tendency to break into shalelike layers or plates. We have considerable trouble in working them, as they are thrown out in very large pieces when blasted, which necessitate mud-capping. One or two sticks of dynamite are placed on a piece, covered with a couple of shovelfuls of mud, and exploded, or the material is broken with sledges to reduce it to a size that can be ground in our dry pans. These shales weather easily and we give them as much of an opportunity to do so as possible by blasting ahead of our working face.

The yellow layer is a typical shale and works easily, presenting no especially difficult features.

The hard, sandy rock is not always present, and never runs thicker than six inches, but when it is present, it is a great trouble producer, as it is hard to distinguish it from the hard blue shale, and a large proportion of dry-pan repairs are directly due to this material.

Our equipment for making stiff mud shale brick and blocks consists of the following machines:

1 Houston-Stanwood engine, 250 H. P.
2 tubular boilers, 250 H. P.
1 9-ft. American Clay Working Machinery Company's dry pan (iron frame).
2 9-ft. Means dry pans.
1 American Clay Working Machinery Company's 12-ft. pug mill.
1 Freese mammoth brick machine.
1 Freese rotary cutter
1 Richardson repress.
11 track tunnel dryer.
8 round down draft kilns, 32 ft. inside diameter.

It is not necessary to enter into a detailed description of the machinery as reference to the catalogues would furnish that, but our dryer and kilns may need a short description.

Our dryer consists of eleven tunnels, with brick walls and partitions, and a tile and iron roof. The heat is fur-

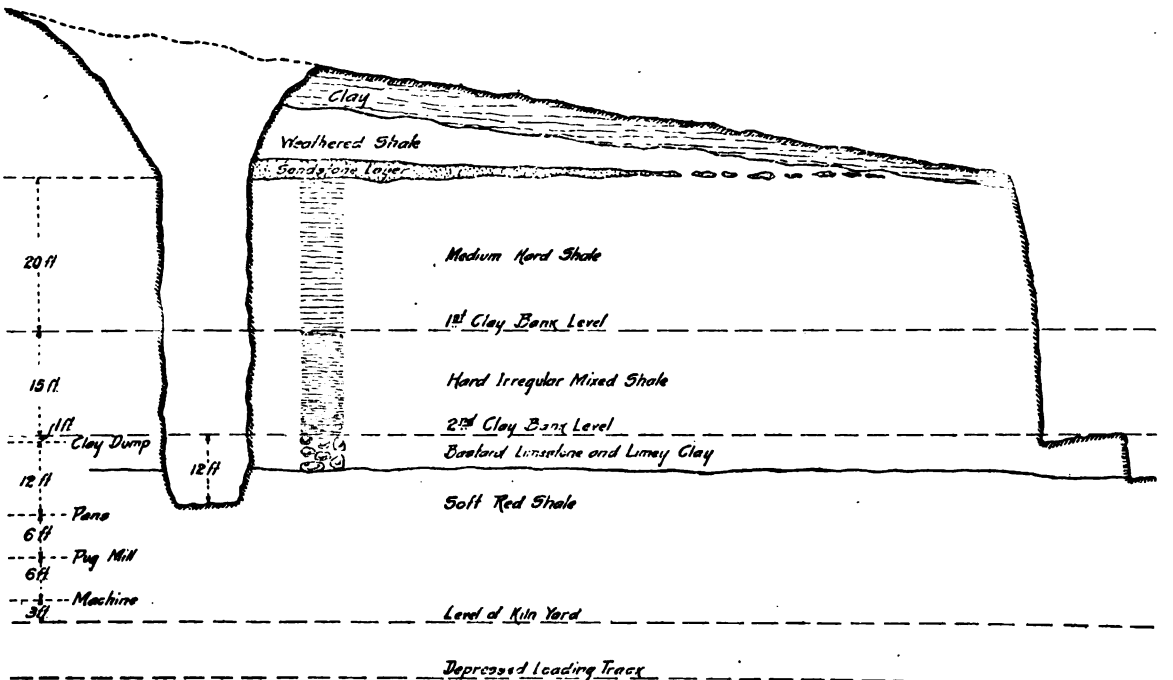


FIG. 2. Cross-section of bank worked by Rosslyn Brick Co., Carnegie, Pa.

nished by a separate furnace and flue for each tunnel connecting with a smoke stack. The water vapor is carried off by a wooden stack at the cool end of the dryer; the fuel is run-of-mine coal.

Our kilns are 32 feet, round down-draft, with ten fire boxes, using inclined grate bars. Their capacity is 80,000 common brick. The fuel is run-of-mine Pittsburgh coal.

In fig. 2 we have shown the various levels of different parts of our plant, and it may be seen at a glance that our product moves continuously downward with the exception of the use of elevators from pans to screen, thus making the mechanical handling very simple.

The list of our employees is as follows:

	Daily Wages.
Foreman	$3.30
12 claybank men	18.25
Screen boy	1.50
2 pan feeders	3.60
Pugger	2.00
Machine man	2.00
3 hackers	5.25
Repress man	2.00
2 transfer men, to tunnels	3.00
2 transfer men, from tunnels	3.00
4 setters, 28c. per M	11.20
7 kiln-burners and tunnel-firemen	13.00
Engineer	1.75
Coal hauler	1.75
Extra man	1.50
Forty men =	$74.10

This number of men make 25,000 to 30,000 bricks per day and with the addition of two or three men in the claybank, the output can be raised to 40,000 per day, the same labor in the machine room taking care of the increased output without increase in expense. This shows the great saving made by running to the maximum capacity. However, during the last year the demand was not great enough to take care of 40,000 per day and it was considered best to run all the time and make only 30,000 per day.

When we are making bricks and blocks at the same time we accomplish this by using a back board on our cutter, so spaced that it cuts five blocks and four bricks, brick and block alternating. In bulk the blocks run about one-half more than the bricks and therefore in our kiln setting we fill the lower third, 12 courses, with bricks and the top, two-thirds, is set with blocks. By so doing, we are able to burn in about two days' less time, as it is not necessary to hold the kiln until the bottom is as hard as the top part. The common brick in the lower part of kiln find ready sale as building brick and we have no soft culls among our blocks.

Both our loading and setting is done by piece work, the prices being:

Loading brick	25c.	per M.
Loading block	50c.	"
Setting brick	42c.	"
Setting block	28c.	"

This we find to be far more satisfactory and cheaper than trying to have it done by day labor.

In conclusion I would say that the chief benefit derived from the use of this form of cost keeping lies in the fact that you have the figures, in cost per M., below which you cannot sell without loss and as all the expense of running the plant is included in these figures there is no danger of blindly taking a contract at a price which you cannot afford.

FORM I. *Statement of Monthly Costs,*

1905.	Manufactur-							
	Labor.						Brick.	
	Regular.	Extra.	Coal.	Supplies.	Fixed Charges.	Total.	Made.	Cost per M.
January	$1,061.30	$91.20	$434.90	$245.30	$200.00	$2,032.70	230,000	$8.20
February	428.35	.....	250.15	79.81	200.00	58.31	45,000	11.00
March	767.35	134.20	304.30	236.90	200.00	1,642.75	112,000	5.20
April	1,806.17	.....	814.97	464.12	200.00	3,285.26	387,000	4.82
May	2,120.48	.....	852.26	392.14	200.00	3,564.88	224,800	5.50
June	1,857.05	.....	615.61	405.35	200.00	3,168.91	176,160	5.83
July	2,010.05	.....	680.51	426.88	200.00	3,317 44	207,300	5.20
August	2,322.40	.....	778.85	410.64	200.00	3,711.89	234,500	5.10
September	2,271.65	.....	877.74	497.34	200.00	3,846.74	254,700	5.00
October	2,172.20	.....	774.68	371.47	200.00	3,518.35	250,000	5.15
November	2,297.55	.....	837.81	453.15	200.00	3,788.51	645,000	4.00
December	2,235.90	.....	860.46	361.98	200.00	4,658.34	705,780	5.18
Totals	.....	.....	.....	.....	.....	$36,493.17	3,472,830	$5.29

REMARKS.

January — Ran only 17 days this month.

February — Ran only 4 days this month.

March — Ran only 14 days this month.

April — Steady run all month.

May — Lost 4 days (broken shaft).

June — Lost 5½ days, (broken shaft; broken pin in pug mill).

Production and Sales for the Year 1905.

ing Cost.		Sales and Receipts.							
Block.		Brick.				Block.			
Made.	Cost per M.	Sold.	Gross Receipts.	Freight, etc.	Net per M.	Sold.	Gross Receipts.	Freight, etc.	Net per M.
65,000	$9.30	75,300	$431.65	$16.75	$5.50	65,000	$650.00	.....	$10.00
25,000	17.40	50,700	408.60	87.25	5.40	51,000	585.00	$5.00	10.40
136,000	7.80	162,000	959.90	48.00	5.62	68,000	810.00	26.40	11.53
195,750	7.23	255,300	7,533.72	79.50	5.70	161,200	1,757.00	22.00	10.76
281,580	8.25	336,200	1,946.57	....	5.70	303,150	3,031.50	.....	10 00
244,800	8.85	180,500	1,069.05	.....	5.92	314,550	3,178.90	.....	10.50
286,665	7.80	176,500	1,072.60	.....	6.07	255,000	2,550.00	.....	10.00
329,300	7.65	217,700	1,268.60	... .	5.80	170,500	1,803.00	.....	10.58
332,130	7.65	238,800	1,321.60	.....	5.55	451,500	4,833.50	.....	10.70
288,884	7.73	319,000	1,785.90	.....	5.60	356,850	3,929.70	.....	11.50
85,760	7.35	526,850	3,268.32	285.60	5.67	67,250	886.87	....	13.18
.....	.....	602,990	3,784.80	308.00	5.78	58,250	786.38	.. ....	13.50
2,270,959	$7.95	3,150,340	$18,847.51	$825.10	$5.72	2,322,250	$24,751.85	.....	$10.65

REMARKS.

July — Lost 1 day, (main shaft coupling).

August — Lost 1 day, (pan repairs).

September —

October — Lost 8 days, (repairs).

November — Lost 1½ days; rain 1 day, Thanksgiving.

December — Lost 2 days; Christmas.

FORM II.

1903.	Clay Bank.	Pans and Machine.	Dryer.	Setting.	Burning.	Loading.	No. of Cars.		Brick Shipped.	Repairs.		Supplies Incidentals.	New Construction.
May.							Made	Set.		Where Made.	Cost.		

FORM III.

51*st Kiln, in Kiln No.* 7.

Made.						Drew.				
Aug. 24—24	cars	brick,	45	cars	block.	Sept. 12—			4,500	block.
25—25	"	"	45	"	"	13—			7,000	"
26—13	"	"	25	"	"		10,800	brick,	19,000	"
						14—15,000		"	2,000	"
							25,000	"	32,500	"

There are 166 cars set in this kiln.
Fired Aug. 25, 6 P. M.
Off Sept. 3, 8 A. M.

52*nd Kiln, in Kiln No.* 2.

Aug. 28—27	cars	brick,	49	cars	block.	Sept. 14—			5,000	block.
29—26	"	"	48	"	"	15—			14,000	"
						16—	8,000	brick,	14,000	"
						19—	12,000	"		
						20—	2,500	"		
							22,500	"	33,000	"

There are 160 cars set in kiln.
Fired Aug. 29, 3 P. M.
Off Sept. 7, 9 A. M.

FORM IV.

Supplies and Repairs bought in December, 1905.

E. M. Freese & Co.	Set of Augers for Machine	$33.50
Black Diamond Mfg. Co.	Belt Fasteners	6.00
C. A. Foster	Horse Feed	4.48
Car. Plow Co.	Repairs	100.00
Car. Plow Co.	Repairs	13.14
H. H. Co.	Supplies	4.07
Wm. Petty	Sand	12.02
H. H. Co.	Coal Shovels	4.50
H. H. Co.	Supplies	1.10
Vogeley Bros	Oil	46.59
E. M. Freese Co.	Machine Die	11.00
H. H. Co.	Bolts	.76
Am. C. M. Co.	Pan Screen Plates	52.00
A. Howell	Freight, Express and Hauling	23.85
John Hayes	Freight, Express and Hauling	22.11
S. Pitts. Water Co.	Water	23.71
Carnegie Union	Printing	3.00
		$361.98

Car improvement	$60.26
Pans	105.03
Pug-mill	4.70
Machine	11.00
Supplies	185.69
Total	$361.98

DISCUSSION.

The Chair: This interesting paper upon the cost of manufacturing common and paving brick is now before the Society for discussion. I am sorry it does not come in its regular place upon the program, when there would be no doubt a larger attendance of brick manufacturers; but there are some facts here which I think should be noted.

Mr. Binns: I would like to ask Mr. Fickes one or two questions. Referring to the total under column headed "net per M.," $10.65, is that block or brick?

Mr. Fickes: That is block. The cost of brick per M. is over here, (indicating), $5.29 per thousand

Mr. Binns: Is that $10.65 the cost of manufacturing the block?

Mr. Fickes: No; that is the selling price, net per M.

Mr. Binns: Where is the total, actual cost of the brick?

Mr. Fickes: Here (indicating), $5.29; and block, $7.95.

Mr. Binns: Is that shale brick?

Mr. Fickes: Yes; shale block and brick.

Mr. Binns: What is the contents of the kiln?

Mr. Fickes: Eighty thousand bricks per kiln.

Mr. Binns: How long do you burn?

Mr. Fickes: We burn common brick in six days.

Mr. Binns: How long do you burn paving block?

Mr. Fickes: About two days longer, eight days, to cone one.

Mr. Yates: Does the cost given include interest, taxes, etc.?

Mr. Fickes: Yes, everything. It is the actual cost, the figures at which we could sell brick without loss.

Mr. Yates: What is your average output?

Mr. *Fickes:* Thirty thousand per day.

Mr. Orton: I want to say in regard to this paper that the fact which impresses itself most strongly on my mind is this, that we have here a style of statement which it is very hard to make popular before an audience, but which does more to raise the technical value of our literature than anything else we can bring out. It fills a gap in our literature which needs to be filled. We have had comparatively few papers along the line of cost of manufacture. The first, I think, we had was the fine contribution of Mr. Ernest Mayer a number of years ago. He gave us a complete analytical statement of the cost of white ware in his plant. That was four years ago. Thas has been of great value to me in teaching along those lines. Those of you in the pottery line perhaps fail to appreciate the difficulties which others experience in grasping the facts as to what it is costing to do their work and where the expense must fall in the division of a year's expense. The use of one concrete illustration like Mr. Mayer's is very valuable and my students have had frequently to refer to it. If you go to the transactions of the larger societies as the American Mining Engineers and American Civil Engineers, you will find statements of costs of all sorts of installations for which they are responsible. I speak chiefly of the mining engineers, because I was connected with that association for several years. If a new mine is opened in South Africa, or anywhere else, in two or three years there will appear a statement regarding the cost and character of the plant, the manner of mining, percent of efficiency, on the cost, etc., going into the minute details. Some will say, "Why should a man give away such information? Isn't it a loss or detriment to him?" The engineer considers that there never was or will be another plant just like that one working under the same conditions, and therefore, what he gives to the public does not damage him

in any way. While it is a fact that no company can ever duplicate his conditions *exactly,* the facts he presents will enable another engineer, in taking hold of a new proposition, to make a better estimate of what the plant may be expected to do. I submit that the ceramic industries are most notobly lacking in this kind of information. It is almost impossible to find in ceramic literature a clean-cut statement of what it costs to do business in any one of the ceramic industries.

I think highly of this paper we have just heard, because it is an accurate statement concerning one particular plant, without any dissembling. There is not a man here working under exactly these conditions. Mr. Fickes pointed out that he is purposely overworking pans and paying bills for repairs in order to level a piece of ground for a special purpose, and it is not likely that anyone else would have such conditions to meet. But an engineer can find something in this statement, which will give him an idea of costs elsewhere.

Now, when we have papers like this on every line of the ceramic industry, it will be possible for engineers to make estimates and designs with more accuracy and they will not miss their mark so widely as they have been doing. I am greatly obliged to Mr. Fickes for giving us this paper.

Mr. Yates: I would like to inquire how long that plant has been in operation?

Mr. Fickes: It has been five years now since we have had brick on the market and five and a half years since we began building it.

Mr. Yates: The cost sheet of any plant is very misleading, taken in the early stages of installation, for the reason that you have to rebuild the plant every ten years. A new plant can start in and make brick for less than an old, established concern, because it has new machinery, new equipment, and they grind out the money and put it in their pockets. They can show the stockholders that they are making brick very cheap and base prices accordingly. At the end of ten years, they have just put back in their

pockets what they first invested and the result is they have no plant or sinking fund with which to build a plant. But they have made themselves believe, during the years they were running, that they were doing a very lucrative business. For that reason the cost sheet is very misleading.

Mr. Gates: I think a paper of this character from a practical man is quite an addition to our literature. I remember a man told me his experience several years ago. He said a man who was a good promoter, a good bookkeeper, had the whole first year's business figured out before he invested any money, all shown in figures and red lines. And his difficulty at the end of the first year was to discover just where he did lose that money. He had to go in and go to work and rejuvenate the company before he got any profit. I think too many of such estimates have been made by good bookkeepers and good promoters. I think many of us have curiosity to know at the end of the first year, just where we did lose our money. This is a good line to follow up, and I hope we will have more.

ON SOME PHASES OF BISCUIT LOSS IN THE MANUFACTURE OF WHITE WARE.

BY

HERFORD HOPE, Huntington, W. Va.

The subject of biscuit loss, which it at all times of some, and under certain conditions of great importance to the manufacturing potter, is one into which it is believed very little systematic investigation has been made.

As the experiments detailed below were made on but one body, an average whiteware body maturing at cone 8, it is possible to give the results only as they were obtained under this set of conditions. No doubt a body of greater or less plasticity, or burnt at higher or lower heat, would to some extent alter the results obtained, while different methods of working used in various clay shops would probably produce types of cracks other than those which have come under observation during these experiments. It should therefore be understood from the first that this paper is not supposd to be in any sense exhaustive.

The causes of some types of cracks are sufficiently obvious to pass over with but little comment, while the causes of others are very obscure and it has taken repeated experiments, (altogether about a hundred dozens of ware have been used) to confirm the conclusions presented herewith.

In some cases they have been only partially investigated, and there I shall be content with giving my own theory which will at least have the merit of being partly borne out by experiment.

Clay Cracks vs. Biscuit Cracks.

In order that there may be no confusion of terms, I wish to state definitely what I mean by clay cracks and by biscuit cracks, when referring to biscuit loss. A clay crack is one that is caused *before* the ware is fired, no

matter whether cracked in drying or strained in handling. A biscuit crack is one that is caused *after* the ware is fired. Some causes of loss, however, must be charged to each of the five departments through which whiteware passes before it is glazed, namely, making, finishing, biscuit placing, biscuit firing and warehouse work including biscuit drawing.

Though practically the whole of the loss which occurs in making the ware should be found and taken out in finishing, either through carelessness or design, a certain amount is allowed to pass and is found in the biscuit warehouse when the loss is examined.

Losses Other Than Cracking.

As this paper is chiefly concerned with the types and causes of cracks originating in unfired ware, it would be well before entering into a discussion of these to dwell for a short time on other causes of loss. These are, for the most part, browned, dirty, crooked, biscuit cracked, dunted, and blistered ware.

Browned ware is caused by the wads on the saggers being broken or knocked off, or by a cracked sagger not being properly stopped with wad clay, or in some cases by a sagger cracking during firing. In any case, flame and cinders are admitted into the sagger.

Dirty ware may have several causes. Iron in a sagger bottom usually appears as a fused globule when it oxidizes and drops on the ware in the sagger below. When the stain of iron appears, indicating the oxide below the surface of the ware, it is undoubtedly caused by a bit of iron or steel which has gotten into the clay before the piece was made.

Copper stains are generally derived from a bit of brass wedging wire or brass screen cloth that has gotten into the clay like the iron mentioned before. Plaster marks in the ware consist of holes, in the bottom of which is a little fused lime. The plaster can usually be traced to the potter's batter, or batting out block, or else to careless scrap-

ping of jollied ware, the mould being occasionally cut by the scrapping tool and the plaster thrown on the back of the piece just made.

An important subdivision of biscuit loss is crooked ware. Its causes are so numerous and in many cases so obscure that they alone would form subject matter for a paper, so some of the probable causes will merely be mentioned. It is hardly necessary to dwell on the warping of dishes particularly the larger sizes due to defective sanding in placing, but since the flat taken as a whole is a large item, a few remarks having special reference to plates may not be without their value.

A plate mould having a steep ball forming the center of the piece, is very likely to cause crookedness on account of the strain of contraction over the ball. Another unquestionable cause is the rocking of moulds in the jolly ring, this being caused either by a little clay getting under the shoulder of the mould, or by the moulds being a little too large for the ring. The use of too plastic a body, and an uneven application of heat in drying are no doubt sources of crookedness. It seems probable also that where bats, made by hand (and often very uneven) are used, particularly where they are not run down by hand, a certain amount of crooked ware is likely to result from the jolly tool touching one side of the bat before the other, thus producing an uneven tension. Crooked setters and cracked and uneven sagger bottoms also contribute largely to loss of this kind.

Although a large percentage of loss comes from biscuit cracked ware, it can be readily separated from that caused before the ware was fired. The edges of the crack in the former will be very close together, while those of the latter are always more or less separated by contraction. Its sound when struck differs from that of other cracks, excepting dunts, (whose fracture instantly distinguishes them) having a vibratory sound not possessed by the others. It is not the purpose of this paper to further discuss biscuit cracked ware at its cause is one, rough

handling, whether the ware is chipped, cracked or altogether broken, depending upon the point of impact and the severity of the blow.

Dunted ware is a loss occasioned by the too rapid cooling of large pieces of ware, particularly where a flat surface is exposed, but the loss is so readily recognized by its peculiarly smooth fracture and the sinuous course taken by the crack that further comment on it seems unnecessary. It is well to add, however, that in many cases, dunts have their origin in a clay crack in the edge, small though that crack may be.

Blisters, resulting usually from defective pugging of the clay, are very evident where they occur near the surface of the ware, a lump appearing above them; though where they occur well beneath the surface, a crack from this cause can usually be recognized by its being short and comparatively wide. In a less plastic body a crack caused by a blister often runs for a considerable distance in both directions from it.

Bad placing which is responsible for more or less biscuit loss will be passed over here as some of its phases have already been referred to under the heads of the loss they occasion.

Clay Cracks.

Having thus briefly reviewed some sources of loss other than clay racks, we will turn our attention to the latter, taking up the articles usually made in white ware which may be divided into five groups: *1st.* Hollow-ware, jugs, covered dishes, etc.; *2nd.* Cups; *3rd.* Nappies and bowls; *4th.* Dishes and bakers; *5th.* Flatware, plates, saucers, etc.

Hollow-ware.

The chief types of loss in hollow-ware are browned and biscuit cracked ware, to both of which I have already referred. To what has been said on the subject of biscuit cracks, should be added here that a large percentage of

the loss in pressed hollow-ware is breakage due to making the ware too thin in places. Next to these two causes of loss come sprung handles and clay cracks. Sprung handles, where the handle has started away from the body, nearly always at the top, are for the most part a loss which belongs to the clay shop, but as it is not always easy to determine how far sprung it is safe to let a handle pass, and as potters are not, as a rule, addicted to the habit of throwing their ware away so long as it may be passed, a certain amount will always find its way into the biscuit ware house.

The chief causes of handles springing are these: Allowing the body or the handle or both to become too hard before sticking up; not cutting the handle to a shape which conforms to that of the body of the piece; and, in sticking up, sticking the lower end of the handle first, thus bending it out of shape when the top is brought into place. This will cause the handle to spring away at the top in the kiln in attempting to return to its former shape. This last, of course, is an error only made by a beginner who has not been shown the proper method.

In my experience, the chief form of clay crack in pressed hollow-ware is found in the bottom, where in making, a roll of clay is used to fill up the depression made by pressing up the feet. A little water occasionally gets below this roll and invariably cracks the bottom. While this crack is usually apparent before firing, it is not always so, and hence must be included here.

If a piece of hollow-ware is made too light at a place which has to sustain a large part of the weight it is very likely to squat or sink down when the highest heat is reached. Comparatively few cases of this occur, but where they do, great precautions should be taken as the loss is likely to assume serious proportions.

Cracks found in jiggered hollow-ware are for the most part of two kinds, which occasionally get through to the biscuit. Both are in the bottom; one is in or near the feet, where after the latter have been pressed up, a piece

of clay, thrown in to fill up the cavity formed, has imprisoned either air or water or both, the inevitable crack resulting; the other is a crack running around the inside of the bottom, and caused by water settling there after the piece was made. These cracks are both apparent before firing and no excuse can be found for their presence in the biscuit.

Cups.

The chief losses in these are edge and bottom cracks and sprung handles, although crookedness and biscuit cracks form a considerable percentage.

The edge cracks are caused either by the cups fitting the sponger's chum too closely, often the case with hard cups; on the handler bringing the cups down too hard on the straightening chum; or, if a straightening ring is used, by the latter being too heavy for the top of a thin cup. This cause, however, is almost always apparent from the spreading of the top.

The bottom cracks are of two kinds; both occur inside on the bottom. One runs around the bottom and is caused by water settling exactly as in the case with the large hollow-ware, though of course all of these should be seen and destroyed by the finisher. The other is found in the form of small cracks radiating from a point in the center of the bottom, and is caused by the finisher pressing on the bottom outside, when, by reason of the cup being too hard and therefore too small to fit the chum, there is a space left between the top of the latter and the bottom of the cup.

Sprung handles, caused as in the larger hollow-ware by either body or handle being too hard, are easily distinguished from those which are knocked off in the biscuit warehouse by the former coming off clean, showing that no union has taken place with the body of the cup, while the latter always come off carrying with them part of the cup itself.

Crookedness in cups may be attributed to a number of causes, chief among which are: Leaving them in the

moulds too long ,when they draw crooked; taking out too soft, when they are bent out of shape in placing on boards; sponging them too soft, and then allowing them to get a little hard before sticking up; one side being thicker than the other, due to irregular running of the moulds, the tendency to go crooked from this last cause is aggravated by hard firing. Although the cups are temporarily straightened on the handler's chum, yet the well known tendency of clay to revert to its original form when soft is often strong enough to again draw them crooked in the kiln.

Of biscuit cracks, little need be said: their sound when struck is so dissimilar to that of any clay cracked ware, except dunts, and their edges are so close together that no mistake can be made in determine their cause.

Browned and copper strained cups are frequently found but in small numbers, and as both sources of loss have been treated of before, it will be unnecessary to refer to them again.

Nappies and Bowls.

In discussing the biscuit loss occurring in this class of ware, which includes basins, it seems advisable to consider separately the two classes — ware whose inside is made with the tool, and ware whose back is made with the tool. For brief reference the terms inside and outside ware will suffice.

The principal losses in inside ware are crookedness and edge cracks. Some of this class of ware is allowed to dry in the moulds and is finished upside down on a plaster chum. When the ware is left in the moulds thus, it often becomes more or less crooked on account of uneven drying and when placed on the chum touches at two points on opposite sides, being straind at these points as soon as any pressure is applied in finishing. This, like much other loss, ought to be seen and stopped by the finisher, but since a certain percentage is allowed to pass, no excuse seems necessary for its mention her.

A fine edge crack, very commonly found in thick

ware such as oyster nappies, low-footed oyster bowls, etc., where each piece does not rest on its foot is apparently caused by the weight on the bottom piece (if it be a little crooked) of several others above it. Whenever this is found to be the cause of loss, the latter can obviously be lessened by reducing the height of the bungs. In addition to these cracks, one frequently met with in inside nappies, particularly the larger sizes, is that caused by the application of too much pressure on the bottom when finishing. The appearance of this loss is the same as that from a similar cause already mentioned under the head of cups, though the cracks are proportionately larger.

In bowls of light weight are found the same types of loss and their respective causes as obtain with cups already discussed.

In outside nappies and basins, the chief type of loss is an edge crack which varies considerably in length. One of the chief causes for this, at least in the case of nappies, is the sliding of the ware when bunged upon the finisher's whirler, some of the pieces being thrown by centrifugal force against the side of the next below them. It seems probable that it is also caused by the fettling tin or finishing tool catching in the scallops of the edge, thereby causing a strain; this opinion being strengthened by the fact that the crack is usually rather long and with the edges not widely separated, whereas all cracks, however small, when they occur on the moulds are, if they get through to the biscuit, very much wider in proportion to their length, this being due, of course, to the two stages of contraction through which the crack passes.

Dishes and Bakers.

As the only dishes and bakers which have been dealt with have been machine-made, it must be borne in mind that the following notes refer only to the loss in machine-made wares.

Ignoring in this instance the item of crookedness (which loss should not be excessive with footed ware, given

reasonable care in placing) the two principal types of loss are both edge cracks, the one large and the other small. The causes of the former are still in doubt, but it seems most probable that they are the same as those found in outside nappies, a crack caused by the ware sliding in the bung during finishing and also a strain caused by the fettling tool catching in the scallops of the edge, though the same crack is produced by the finisher picking up the piece too near its edge, or in turning it over to sponge the back, allowing it to fall against his arm with too much force.

The small crack is usually, perhaps always, a scrap crack, having its origin in the clay left on the mould in the scallops of festooned ware, and being visible in the unfired piece only under the closest scrutiny.

This loss is much reduced by the use of moulds with a richot or deep groove in the spare edge, making the scrap crack off all around the edges of the piece before any cracks can run up into it. This will also tend to reduce considerably the loss by the first mentioned crack, as the ware leaves the moulds with a clean edge much less liable to catch the finishing tool than is the more ragged edge resulting from scrapping the ware up close with a wire frog.

It seems like a serious omission to make no mention here of dunted dishes, but in most cases the dunt has its origin in an edge crack such as has just been described.

Flat Plates and Saucers.

As the loss in plates differs in some respects from that found in saucers, it will be better to treat each separately. The chief loss in plates aside from biscuit cracked and crooked ware, the former of which is, as has been previously mentioned, almost invariably detected by its sound, consists of clay cracks of three distinct types, while several other kinds, the causes of which are at present undetermined, go to make up the remainder.

Of the three cracks referred to, the first is a long one,

always crossing the foot of the plate and extending about an equal distance on either side of it; though the chief characteristic of the type is that it rarely reaches to the edge of the piece, unless dunted the rest of the way, which is often the case. This crack is caused by the foot of the plate being crooked, very often from the moulds rocking in the jolly ring, the weight of the others above it forcing it into contact with the next below and straining it thereby. The same result is produced by placing the ware on crooked setters or on crooked boards without setters.

The second type of crack consists of three secondary cracks radiating from a central point, the latter indicating where the plate has been struck, this being usually done by the finisher in transferring the ware from his whirler to the finished bung.

When a plate is stuck inside another with less force, if there be impact enough to crack the latter piece at all, the crack will be found on the back as a curved mark corresponding to the shape of the foot of the piece which struck it. On the face of the plate there is usually a slight depression of the same shape, and not infrequently a little clay from the foot of the other plate.

The third kind is an edge crack extending from a quarter of an inch into the plate. It has been definitely determined that one cause for this is the handling of the piece in one hand causing a strain on the edge, though it is probable that other causes, at present unknown, contribute largely to the same result.

Among other causes of loss in plates may be mentioned the uneven bunging up of the ware, loss being almost certain to occur if some of the lower pieces are out of line. Taking into consideration the comparatively low tensile strength of an average whiteware body and the weight of, say a dozen of plates, it is very evident that if the foot of each is not in line with the foot of the next above, a great strain will be exerted on a part of the plate unsupported by the foot.

The phenomenon of plates flattening out in drying, as

yet unexplained, wherever it occurs in a marked degree, is also responsible for loss, as when a flattened piece is placed inside one whose rim has the normal shape the two rims touch and the weight of all the ware above rests on the extreme edge of the rim, with the result that one or both plates must crack, or perhaps break altogether. Where this occurs with sufficient frequency to make it worth while, the foot of the plate may be made a little higher, and the loss thus averted.

In cases where plates have been made too light in the centre, a considerable loss is sometimes experienced from the application there of too much pressure in finishing, the resulting loss appearing in the form of secondary cracks, radiating from a common centre much the same as that occurring in the bottom of cups and nappies and already referred to under those heads.

Among occasional cracks may be mentioned two, which, while they are both apparent before firing, frequently find their way through to the biscuit. I refer to scrap cracks and cracks of a certain type peculiar to deep soup plates, covered butter bottoms and other ware of a similar shape. This latter varies in length from a fraction of an inch to several inches, though of course only cracks of the smallest size are found in the biscuit. It occurs at the angle formed by the rim and the ball of the plate and is caused by the jolly tool coming to too sharp a point there.

Scrap cracks, originating in the clay left in the scallops of the mould are easily recognized by almost always running in from the edge at an angle of about 45 degrees to it, differing from all other cracks in this respect — and by their short length, which rarely exceeds three-eighths of an inch. As this is the chief loss experienced by the potters and as a heavy loss on the moulds always means an increased biscuit loss, it being only just to say that many of these scrap cracks are very small and hard to see, it may not be out of place to remark that the use of a rather heavy

bodied oil on the moulds will often prevent this crack altogether.

Further, loss of this kind will be reduced by keeping the jolly tools sharp and in good shape. The writer has in mind at this moment a case when a few strokes of a file in the right place reduced a loss on the moulds from 15 or 20 to less than ½ per cent.

Taking up the second division of flat ware, viz., saucers, the same three cracks referred to in the loss of plates, are found though the edge cracks from a much greater proportion in the case of saucers.

As the general appearance of each of these three cracks is about the same as in plates, it is unnecessary to repeat their description. The edge cracks in saucers may be attributed in a greater degree than in the case of plates, to their being handled in one hand, though just what proportion of loss may be accounted for in this way is very difficult to determine.

The loss caused by pressing too heavily on the centre of the saucer either with a finger of the left hand when cutting the edges, or with the sponge when sponging, is proportionately much higher than in plates, on account of the bottom being thinner. As usual with loss from this cause, it is easily recognized by the depression of the bottom and the radiating cracks apparent on the lower surface.

A source of loss which only occurs in saucers to an appreciable extent, is in allowing a piece of fired wad or other hard substance to get into the sand sprinkled on the sagger bottom. A bung of saucers is placed on it, and as soon as the body softens under heat, the bottom is pushed up, having an appearance as nearly as possible the reverse of the crack last described.

Having now discussed the various kinds of biscuit loss commonly met with, and having to a large extent determined their causes, let us see what conclusions we can draw therefrom as regards the prevention of loss.

Speaking in general terms, the principal causes of biscuit loss are as follows:

1st. Low tensile strength of the body.
2nd. The tendency of ware to become crooked in drying and the consequent strain when straightened.
3rd. The use of clay from which air has not been eliminated in pugging.
4th. Hard and uneven firing.
5th. Careless handling of dry, unfired ware by the finishers.
6th. The application, in finishing, of undue pressure to unsupported portions of the ware.
7th. Rough handling of biscuit ware in the warehouse and in drawing.
8th. Bad placing.

Taking these causes in order, we find as the remedy for the low tensile strength of the body, the addition of ball clay, though, by its greater contraction, it has a tendency towards crookedness, thus partially offsetting the benefits derived from its toughening qualities.

The second item, crookedness, may be avoided to a large extent in several ways: By avoiding the excessive use of plastic clays in the body; by allowing the heated air used in drying free access to all sides of each mould, a matter almost impossible with the type of stove rooms now in general use; by careful attention being given to the fitting of the moulds in the jolly rings; by avoiding over firing, etc.

The air which has not been properly eliminated from the clay comes from two sources; the re-pugging of scrap which, on account of its being in small pieces and consequently full of air, should have gone back to the blunger; and a defective pug mill. The remedy for the first is obviously the more careful selection of scrap for repugging, while that for the second is more difficult to determine.

The angle of the knives and the relative speeds of the

vertical and of the horizontal shafts in a vertical mill are the most important factors in pugging.

Hard and uneven firing which is responsible for much crooked ware can be remedied only by greater care on the part of the fireman.

The last four items, being occasioned solely by carelessness on the part of employees, a tendency which seems inherent on the part of most, can be remedied only by increased attention and care on their part.

In conclusion it should be stated that throughout the course of these experiments and in the experience of the writer, there has been no evidence of any crack, with the exception of dunts, originating in the firing itself, so that with the above exception and that of biscuit cracks, the origin of all others may be found in the clay state.

DISCUSSION.

Mr. Binns: I do not know what it is in human nature, but there is something which makes it extremely satisfactory to find that a man has gone through trouble which you have gone through yourself. There is a satisfaction from another standpoint: We who are becoming veterans in the whiteware field like to see the enthusiasm of a young man covering the same ground. I would like to know what means Mr. Hope has found for more effective workmanship, which is the cause of most of these troubles.

Mr. Hope: As far as careless workmanship goes, I have nothing to offer. It is a personal sort of question, something which can hardly be controlled. I do not know what to offer that is new. That conclusion of my paper is very lame, but I do not know of anything else to say. It someone could make a suggestion along that line, it would be valuable.

Mr. Binns: The point in my mind would be, that if the manufacturers could avoid a strike, insisting upon perfect goods from the kiln would largely eliminate these troubles, but I do not think it is possible to do this. I am

very sure the potters know the causes of the troubles and I am perfectly sure that ninety per cent. could be avoided, but unless we can insist upon the goods being delivered in perfect condition to the warehouse, we cannot help the trouble.

Mr. Ashley: I have here an illustration of the means used by one company in following up biscuit loss. It is a diagram used by this company, which has three plants. Every week for each of these plants the total value of broken biscuit ware is determined. The average value of the kiln is multiplied by the number of kilns drawn that week, and deducting the value of the broken ware the per cent. of loss is obtained. In plant No. 1, for the year ending July 1, 1906, the percentage of loss is given here by this red line (indicating on diagram), for No. 2, here, and for No. 3, here. The weekly averages are shown here. (Explaining details of diagram.) The foremen and I get together each week, these figures are brought together and discussed, and if we can locate the trouble, the foreman goes to the man or men responsible, and along with him goes the superintendent and assistant superintendent, so they have the feeling that it is being followed up. The percentage varied from three to four and a quarter percent the previous year.

Mr. Stover: Concerning this question of difficulty in locating the trouble among workmen, human nature is much the same wherever we find it, and in dealing with workmen, we must remember we are dealing with human beings. The foreman usually forgets that, and when anything goes wrong, he goes at the man with hammer and tongs. If they would use a little diplomacy and let each man understand that upon his success depends his salary, that each man must bear his own burden, it would be found that frequently men could be led to agree to what is claimed to be his fault if it can be proved. If you can get that sort of an agreement from a man, that he will stand for a fault if it is proved to be his, you go a long way

to effecting better results. It is a matter of diplomacy rather than main strength.

Mr. Hope: I agree fully with Mr. Stover's remarks, and I believe if you treat men tactfully and in the right way more will be accomplished than is generally being accomplished. Of course many men, especially just now, have to be driven to work; but with many others we can appeal to something better than that, and I have found from personal experience that this method meets with better results. I have men in the factory today who, if they had been treated in any other way, would not be taking the interest they do in their work now. I do not agree with Mr. Binns that potters know what their loss is. If they know what it is they fail to reduce it. It is because they think you don't know, that little attention is paid when they are shown the loss.

Mr. Stover: I remember a case of this kind a couple of years ago, where there was a loss, and the men threatened to strike rather than stand the loss. After we agreed on a basis of settlement, we got the men to agree that if the trouble was proved to have started from their work, they would stand for it. In this way a strike was averted.

Mr. Rivers: We have found that self-preservation is the first law of nature in animal or human. In other words, you can appeal to a man more directly and effectively through his pocket than by any other method. We have some men who can make a better average than others. I figured out what average I ought to get from the presses and offered a percentage of increase to the pressmen. I offered a slight addition after a certain percentage of loss was allowed for the kiln; if the man in charge of the kiln has secured results above the percentage of loss agreed upon, then he gets a certain percentage of that profit. They would grumble very much if we were to take off a small percent; they were willing to share the profit, but not the losses. We find we get the best out of a man when he is feeling best, and he is feeling best when he gets a little more in his envelope on Saturday. We, as manu-

facturers, are apt to look at only our side of the loss, instead of considering that we have some bright men to deal with, some of them much brighter than we think. If we want them to take the care we wish they would, we must show them something in return for it. It is only by putting the men on their individual merits that we will get it. If you have two men making plates, and one has a little larger percentage of loss than the other, providing the plates of the one are not put where cold air will make dunting a legitimate loss, give the man who makes the best plates a percentage of what he saves, and you will find it will bring better results. We find it one of the best possible methods of getting it. We were making large pieces, and were thinking that the more we got in the saggers and the more the kilns would hold, the more money we would make; but it was not the case. We found that when we made the saggers a little larger and kept the edges of the plates or tiles further away from the edges in the first heating of the kiln, the sagger would get heated more uniformly and the danger of cracking was decreased. To prevent dunting, we found we must not cool so rapidly, but exhaust the hot air from the kiln, letting in as little cold air as possible, instead of admitting the cold air at the bottom and forcing the hot air out of the top.

Mr. Gates: I was considerably amused at the very careful and intelligent analysis of the different cracks, as shown here in this business. I had thought we had the meanest business there was in the clay line, but we only have two classes of cracks, *bad* and *worse.* I thought at one time there would be a third, *worst,* but the worse has always been so bad I have never been able to find a "worst." I was called away as the remedy was being shown, but it strikes me as original. If I understand it correctly, the remedy suggested is to buy two more plants and then compare the one with the other two. I am going to think that over.

INQUIRY INTO BODY DISSOLUTION AND ITS CAUSES.

BY

CHARLES WEELANS, Trenton, N. J.

In taking up this subject clothed in mystery and involved in difficulties, the writer would like to state that he in no wise presumes that this short note will point out all the dangers or that it will prescribe for each a remedy. On the contrary, should he be successful in arousing the interest of members, abler and better fitted than himself, to assume this task, more will have been accomplished than he could have hoped for or anticipated. Not being able to find any data upon the subject save his own experience, the problem was made more difficult of solution and ultimate success less assured.

That it is a burning question can be attested by the fact that probably no manufacturer of heavy vitreous ware is entirely free from its ravages, or fully appreciates its causes.

Beautiful pieces of workmanship, perfect in every detail, upon which much thought has been spent have found their way to the profitless pit through the development of this fault. We congratulate ourselves in the evening only to condole with ourselves in the morning. The irregularity of its occurrence increases the annoyance and deepens the mystery. Nor is the fault confined to heavy pieces alone. It may appear in pieces less pretentious and valuable.

It is true much benefit is to be derived by paying close attention to the conditions attending the progress of the warefrom the time of moulding to the time of firing. Good clay storing facilities should be secured, particularly for the body after being prepared for use. It should be aged before using, and its condition when taken from filter press should be in a state of plasticity as nearly that re-

quired for immediate use as possible, and maintained thus throughout the so-called time of aging.

Frequent applications of water to return hardened lumps of prepared clay to the proper consistency for use, is known to be a detrimental practice.

An even temperature of the work-shops is also very desirable, for it is evident that much injury is often caused by the changes of season or sudden changes of temperature, particularly in winter.

The drying facilities should be good and kept in constant control. Drafts which cause the projecting parts of the ware to dry more rapidly than the heavier parts and subsequent rapid and unequal contraction resulting in dunting and cracking of the ware should be avoided when possible. Artificial means of protection against this danger have been used with some benefit. Many new innovations have been suggested by technical men looking to the better protection of the ware in its progress to the kilns. The introduction of these methods has been slow, however, due probably to the conservative disposition of the average potters, who usually shrink from the application of any theory that does not promise both satisfactory and immediate results. I was formerly indifferent and somewhat opposed to the introduction into the factory of any idea evolved by the so-called "paper potters," always believing that their theories were but fancies fashioned in the air, and practical only in dreamland.

I have since, however, learned the value of the school of science to the pottery industry and, while the knowledge now extant is but small in comparison to that which is yet to be known, it is still a guiding light in the potter's pathway of progress. Therefore, despite the apparent indifference to scientific methods, any device that could successfully control not only the temperature but also the humidity of our work-shops and dry-rooms during the changeable seasons would probably result in benefit not now fully understood or appreciated.

The ware being ready for the kilns calls our attention

to the satisfactory arrangement in saggers necessary for first time burning. We have been surprised at the wonderful changes from bad to good that have been brought about by simply changing the arrangement of the ware in saggers for burning. Weight, shape, style, and construction of the pieces to be burned must be well considered before placing, if satisfactory results are to be attained, for dunting is not only a glost trouble but a biscuit trouble also. In fact we are often unable to discover the trouble while ware is in the biscuit state and the fault is many times attributed to the glost fire when the damage really occurred in the biscuit.

After firing comes the cooling. In many factories all the time and in all the factories some of the time this is a period in the progress of the ware, which receives much attention and rightly so. Slow cooling is advisable; hence after firing, care is taken that all openings in kiln are closed and cold air is prevented from entering as much as possible.

Care in the above features of our business as well as others not mentioned, all contribute to the safety of our product and its freedom from dunting. Yet as will be seen, good results are much dependent upon the operator, hence our success is a fluctuating success, continually rising and falling, and as is the case in certain classes of pottery manufacture, the tide sometimes gets pretty low. To be eminently successful, therefore, it would seem necessary that while we are observing all the rules for safely conducting the ware from stage to stage in its progress toward completion, we should especially devote ourselves to the greater problem of its composition and the fitting of it to proper temperatures in burning. With this thought in view, the writer has done some experimenting to ascertain some facts pertaining to the body composition most practical for those large, vitreous, peculiarly constructed pieces known as sanitary ware, and the treatment most suitable for them.

Remembering, therefore, what was said in the preface

of these remarks regarding the newness of the subject and the lack of any data that could be used as a guide, I will proceed to give the results of our experiments in the following points, taken in order: *First, overfire. Second, underfire. Third, defective construction. Fourth, weak body.*

Overfire.

In discussing the point of overfire it may be said that when ware dunts from overfire, it is often stated that the main cause is a body composition unsuited to the heat used. There is evidently some truth in this statement, just as it is also true that when ware is fired in a damp condition and is taken from the kiln badly damaged, the fault can, with apparent truth, be attributed not only to the damp condition of the water, but also to a too sudden application of heat.

To eliminate faults of this class, therefore we selected body No. 4, series I, which, in previous experiments, had, when conditions were suitable, proved satisfactory and free from the faults under discussion. A number of pieces were made up, carefully dried and fired at cone eleven.

When drawn from the biscuit kiln a number of them were found to be dunted. These dunts were so fine, however, that all were not detected in the biscuit state. After the glost fire, but few of the total number were found to be good. Those, apparently good, were drawn from the glost and were placed away for future inspection. After a time these were again examined and though coming from the kiln in apparently satisfactory condition many of them were found to be dunted. Out of the entire batch, therefore, but few stood the test.

Efforts were made to try and determine just when this dunting took place in those which were good when first drawn from the kiln.

Could it be that this action was as sudden as it appeared, or had it begun in the body at the beginning of the cooling? To try and determine this, a number of

small pieces were made up of the same shape as the larger pieces. Part of these were allowed to dry in the usual way. Some of them cracked, others were good. The cracking began slowly and increased in extent until the clay reached a comparatively dry state. The other pieces made at the same time were taken from the moulds and as soon as the moisture evaporated from the surface, they were taken up with the hands and with the fingers rubbed until the surface became quite hardened. This was repeated at certain intervals until the moisture ceased to rise to the surface and they arrived at a state of dryness nearly approaching the point where the former pieces cracked. They were then allowed to continue drying in the ordinary way. Few of them escaped dunting and, though in the clay state, all in dunting emitted a sound similar to that heard when this action takes place in fired ware. Is this not an indication that dunts, like cracks, begin slowly and not until the glaze is fractured are we enabled to discover it?

We took this and other similar experiences to indicate that, since the body used came from the kiln good when fired properly and remained good, yet invariably dunted at a higher fire, that the cause could with reason be attributed directly to the heat used.

Underfire.

In the manufacture of pottery fired in kilns of large cross section, it is extremely difficult to treat all ware alike. To be reasonably sure that none of the ware will receive too light a fire it would probably necessitate the overfiring of a portion of it. This is a delicate point. To overcome this, some manufacturers use two distinct body compositions. The difference between them is measured according to the probable difference in heat in the various parts of the kiln. Some manufacturers select such pieces of ware for the high temperature parts of the kiln as will bear it, while the more complicated pieces are put in the cooler parts. The firing is then made as nearly suitable to the low temperature parts of the kiln as the high

temperature parts will permit. In this way we avoid as much as possible the light fired ware, which is of so much annoyance particularly to manufacturers of vitreous goods.

To give an illustration of the horror some manufacturers have of light-fired ware I will relate an experience I had in my earlier years in this connection. Much complaint had been made by the superintendent of the factory. The ware had been light-fired, and required refiring in biscuit. Becoming disgusted at the foreman, the superintendent took a hand in the work. We all looked for an immediate remedy. Several kilns had been fired and it came time to draw them. We noticed the superintendent was not on hand. This lack of curiosity on his part seemed strange, indeed. The kiln was drawn and the result to us seemed appalling. Even the saggers failed to hold up. Thinking the superintendent knew nothing of this outcome and fearing his discovery of it upon his return next day, few of us had the courage to face him. Only the foreman seemed satisfied with the result. We were busy examining the damaged ware when the superintendent approached and to our surprise, instead of having a scowl on his face and a kick in his voice, jubilantly exclaimed: "Well, there is none of it light, any way."

Only certain kinds of light-fired vitreous ware will permit of a second treatment in the biscuit. Large light-fired pieces seldom come from the second biscuit firing in a satisfactory condition. Usually the outer parts of heavy ware in light- or high-fire pieces receive more heat than the inner parts. The parts of the ware furthest removed from the surface, therefore, is much the lightest fired. The difference in contraction corresponds to the difference in the heat received.

The light-fired, unlike the high-fired ware, is probably only fused or partially so on the outside and is therefore unable to withstand the strain of cooling, hence dunting takes place.

The fault of light-firing is, according to the experiments made by the writer, a greater danger than overfiring and probably is more likely to occur for the reasons given.

Dunting at Decorating Heat.

There are occasions when pieces coming from the glost kiln slightly defective are refired in the glost and the defect removed. This third firing at the comparatively high heat is not considered particularly dangerous. We decorate these pieces, however, and fire them at decorating heat and the percentage of loss through dunting is at times considerable. In our effort to determine the cause of this phenomenon, we fired a number of pieces at decorating heat and to obtain as nearly as possible the same condition in glost firing we paid no attention to the possible effect in the cooling.

We therefore began to fire very slowly, gradually increasing the heat until finished. We afterwards protected the kiln from cold drafts as much as possible and to further protect the ware, we had placed tile on the inner sides of the kilns and filled in the crevices of the muffle. This care apparently availed but little, for when drawn most of the pieces were found to be dunted.

Having had the same treatment as in the glost, or as nearly so as possible, the only difference being in the temperature attained, why should such a large proportion of the ware dunt? Can it be that in the decorating heat the consequent expansion disturbs the molecules of the composition which through lack of fusion are unable to retain or create a new union? Is this weakened and unable to stand the strain to which it is subjected in cooling?

Being unable to determine this point, the matter was referred to Professor Orton and, as is usual with the genial professor, we received a prompt response.

His advise was that since the above hypothesis was but assumed it would be wise to make an effort to prove or disprove the same by taking the pieces dunted in the decorating heat and refire them in the glost. If our as-

sumptions were true the piece should reunite by again fusing. We were given to understand, of course, that this would not be practical, but merely a means of determining the point in hand. We therefore secured a dunted piece and, while we had no faith whatever in expecting a satisfactory result, we were very much surprised to find the original dunt partially healed and a new dunt starting at the point of the original one. We were unable to determine, however, whether or not the heat attained in this firing was the same as had been reached in the original glost heat, or whether it was higher. Therefore, while not fully proving our hypothesis, this experiment fortified it to the extent that when opportunity affords we shall try it again.

The body composition that proved in our experiments to be the best fitted for this decorating test was No. 8, series I, burned in biscuit at cone 10.

Defective Construction.

Experience has taught some few lessons in construction which probably should be considered in building large complicated pieces of vitreous ware. In joining various parts of certain pieces it is often the case that the parts are not of equal dryness, hence cracks result. This is a common fault and though well understood occasions considerable loss and is often erroneously attributed to other causes. Joining of thick and thin parts is also a source of danger and dunting from this fault generally occurs at the thinnest place, most nearly approaching the thick parts. Sudden and abrupt turns, sharp corners, strains caused by level pieces joined to curved parts, all contribute to this fault of dunting.

Should two parts of a piece be permitted to touch each other by accident, or if not firmly joined, dunts will invariably occur. This often happens where the piece is complicated and the operator has no access to these parts after once joining.

Clay cracks often cause dunting in the biscuit fire,

but are rarely discovered until after being drawn from the glost kiln.

This fault has some apparently peculiar tendencies. Pieces with large cracks in the biscuit remained good in the glost, while others with very small clay cracks, developed in the biscuit, have been found dunted after the glost fire.

Our only explanation for this is, that where the piece is already defective in the clay state and firing is either too high or low, even though the crack be small, there is a strong tendency to dunt from that crack, while if properly fired, though the crack be large, often the piece will appear in good condition from the glost fire.

Weak Body.

In this connection many experiments were made, as the formulas given in the following table of compositions will indicate. These bodies were made up into small pieces in the shape of a closet bowl and many of them in large pieces of similar shape.

COMPOSITION OF BODIES, BURNED IN BISCUIT AT CONES 8 AND 11.

Series I.

No. 1.	0.367	K_2O	Al_2O_3	4.15	SiO_2
No. 2.	0.343	"	"	4.43	"
No. 3.	0.317	"	"	4.74	"
No. 4.	0.288	"	"	5.07	"
No. 5.	0.260	"	"	5.43	"
No. 6.	0.224	"	"	5.82	"
No. 7.	0.188	"	"	6.24	"
No. 8.	0.148	"	"	6.71	"

Series II.

No. 1.	0.342	K_2O	Al_2O_3	4.43	SiO_2
No. 2.	"		"	"	
No. 3.	"		"	"	
No. 4.	"		"	"	
No. 5.	"		"	"	
No. 6.	"		"	"	
No. 7.	"		"	"	
No. 8.	"		"	"	

Series III.

No. 1.	0.148	K_2O	Al_2O_3	6.71	SiO_2
No. 2.	"		"	"	
No. 3.	"		"	"	
No. 4.	"		"	"	

Series IV.

No. 1.	0.188	K_2O	Al_2O_3	6.24	SiO_2
No. 2.	0.171	"	"	5.47	"
No. 3.	0.156	"	"	4.81	"
No. 4.	0.144	"	"	4.26	"
No. 5.	0.134	"	"	3.81	"

Series V.

No. 1.	0.188	K_2O	Al_2O_3	6.26	SiO_2
No. 2.	0.171	"	"	5.47	"
No. 3.	0.156	"	"	4.81	"
No. 4.	0.144	"	"	4.26	"
No. 5.	0.134	"	"	3.81	"

It was the writer's desire in these experiments to ascertain, if possible, some facts as to which of the articles usually employed in vitreous body composition, and the proportion of the same, contributed mostly to the strain-bearing qualities of the body when receiving proper treatment.

As will be seen in series I, we start with a high spar content and low flint and end with high flint and low spar, keeping the clay constant with proportions of the four kinds, namely, English china clay, English ball clay, American ball and Golding's ball clay.

Our object in making up these tests as shown in series I was to ascertain at what point in a body comsition of 60% ground materials, burned at cone 8, the following defects were removed:

First, cracking in clay.

Second, blistering.

Third, dunting.

Without discussing the series in detail, suffice it to say that the most satisfactory numbers of these series were numbers 4 and 5, where the per cent. of flint had risen to

25 and 30% of the total mixture and the spar to 35 and 30%.

In series II we retain the same total per cent. of ground material but, starting with 45% of spar and 15% of flint and keeping them constant, we drop the English china clay and Golding's, substituting American and English ball clays in equal proportions in the beginning in the series, and in the following numbers we increase the American ball clay until 40% of the total mixture was reached. We then decrease it, substituting English ball clay until by the end of the series it too attained 40% of the total mixture.

The object of this was to secure the comparative effect of American and English ball clays and their bearing upon the subject under discussion when using a body high in spar and low in flint.

Our results indicated that English ball clay prevented cracking in clay, caused blistering in firing, where the spar was high, and when large pieces were made resulted in increased dunting.

In series III, we changed the clays in the same manner as in series II, but reversed the per cent .of flint and spar. This was an effort to demonstrate the value of high flint. We burned them at cone No. 12. The trials came from the kiln entirely free from the trouble noticed in series II, and in addition were all free from cracks in the clay. When made in large pieces the result was the same, but for most pottery it was probably too high in flint and the heat required was too great to be practical.

In the five tests of the series IV, we abandoned the use of what is commonly called ball clay and started with 40% of flint, ending with 60% of English and Florida clay.

In each succeeding number we reduced the flint 5% and increased the English clay 5%.

The results were, that all of the numbers cracked more or less in the clay state and in the last two numbers, when made in large pieces, were particularly sensitive to dunting where the fire was too low.

In series V, we desired to determine, if possible, whether or not a substitution of any other clay for English china clay would improve the conditions found in series IV, changing the per cent. of flint and keeping the spar constant, as in the previous series. We therefore substituted Golding's clay, keeping the same constant at 20%, while we increased the Florida as we did the English clay in series IV, beginning with 20% and ending with 40%.

Much improvement was noticeable, as several numbers were free from cracks in the clay state and after firing. Large pieces showed a similar result when stronger clays were substituted for the weaker.

In summing up the results of these tests, stating them briefly, we found what appeared to be the following recommendations:

To Reduce the Tendency to Dunt:

First. Avoid the two extremes of heat.

Second. Observe the rules of pottery construction closely.

Third. In vitreous body composition the following essentials were found to hold:

A. Use English ball clay with care, for while it may be a source of strength used in propor proportion, an excess is weakness.

B. Use such other clays than those mentioned as are found desirable, but select them with a view to their tensile strength rather than for some of their other qualities.

C. Do not depend entirely upon high spar for vitrification, in the desire to use a low heat, but increase the flint and fire as hard as the safety of the ware in other directions will permit.

DISCUSSION.

Mr. Weelans: I have here two or three pieces showing what I consider dunting. I presume these dunts will be very familiar to some of our Trenton potters, though

I do not know how many are present. I will pass these samples for inspection.

The Chair: Mr. Weelans' exposition of this difficult subject must be of interest to many members and I trust will be thoroughly discussed. We have with us a number of practical potters and will be pleased to hear from them.

Mr. Stover: I want to express my admiration for Mr. Weelans in that he had the courage to attack such a difficult problem. I think almost anyone who has attempted to make sanitary ware knows more or less what dunting means, but I think very few of us know what is the cause of it and would undertake work upon a subject of that kind with so little data to start with.

Mr. Binns: I would like to get quite clear what Mr. Weelans means by "dunting." One of these pieces is distinctly clay-cracked and not dunted. As I understand it, a dunt must have a cracked sound. A dunt is a rift in the clay, a rift on the second or third fire, not before, and is a perfectly clean fracture. A clay crack is a granular fracture and often gives rise to a dunt. This is the commonly accepted definition.

Mr. Weelans: If Professor Binns will look at all the samples he may see some that are dunted.

Mr. Binns: You do not include all the samples as examples of dunting?

Mr. Weelans: By no means; they explain themselves.

Mr. Stover: Another peculiar thing about a dunt is, that pieces may come from the kiln in perfect condition and remain so for many months, and then suddenly go off like a gun or pistol. I have not found an answer for the question why a piece which has stood up for a year or more, not subjected to any change of temperature, not in use, should show this fault. I know of a case of this sort which happened right in the store room. I do not know whether anyone can answer that or not.

Mr. Hull: In this connection I would like to ask whether this large ware is held at a finishing temperature

long enough to get the same degree of vitrification throughout the body?

Mr. Stover: It is supposed to be; but whether it is or not, is another question.

Mr. Hull: We manufacture what might be called "ultimate" sanitary ware (sewer-pipe). In making the double strength pipe in the larger sizes, we take the material up to the point at which it will glaze, without attempting to hold the temperature long enough to get the thick pipe thoroughly vitrified, or get it uniformly burned through. On the largest sizes we have made, of which we made only a small number and did not get the finishing process to the point which must be reached to make a permanent article, the pipe all cracked on the yard, showing what sewer pipe people call air cracks. After the ware has been on the yard a number of months long zig-zag lines of cracks are seen along the surface. They are very apparent after a certain time because they become blackened with the soot. I have found the same condition existing in sewer pipe that are not thoroughly oxidized. A pipe, as small as fifteen-inch, which has not been burned with a view to oxidizing it perfectly, so that it has a black center extending to within a quarter inch of the surface, will invariably crack on the yard. Now, I attribute it to a lack of equilibrium, due to a difference in vitrification between the center of the body and the material on the outside. In the case of the large, thoroughly oxidized pipe, the outside is vitrified to a greater extent than the interior, while in the case of the unoxidized pipe, the interior is perhaps vitrified more because of the ferrous condition of the iron. In either case, we have a lack of balance in that respect, and in either case it invariably cracks on the yard.

Mr. Stover: Through the outer section, or all through the piece?

Mr. Hull: It usually does not extent all the way through. The cracks are quite likely to run on the outside and inside without reference to each other, but they predominate on the outside. And sometimes pieces having

these cracks emit a pretty good ring when struck, though as a rule they do not.

Mr. Stover: That seems a different case from the dunt referred to in this paper; because one is really a crack running all the way through, rather a fracture than a surface crack. Your case would be more of a surface crack and I think attributable to the cause you describe. But it does not seem to me the cases are parallel. A dunt is a clean cut through the body. A dunt has a smooth, glassy appearance, while a broken fracture alongside will have a crystalline character.

Mr. Binns: I think the difference there is easily adjusted. Mr. Hull's trouble is no doubt the same, but the greater elasticity of the more granular body prevents the crack from always passing through. But there is no doubt that in both cases, one part has a greater tension than the other, and it all goes back to the question of co-efficient. That is, the more silica a body contains and the finer the grain, the higher the co-efficient and the greater the liability to dunt. Vitrification plays a less important part than the question of co-efficient and fineness of grain. I will ask whether the formula is calculated from scientific calculation or actual composition?

Mr. Weelans: I calculated it from the materials used. I had an analysis made, but did not receive it in time to use.

Mr. Binns: These calculations are from actual analyses?

Mr. Weelans: No.

Mr. Binns: From calculated analyses?

Mr. Weelans: Yes, sir.

Mr. Binns: Here is a piece badly blistered and attributed to English ball clay. If you had taken the rational analysis and adjusted the mixture, you would find it due to the higher content in alkali. You should use alkali there as a basis for calculation. It is unsafe to make a mixture, pound for pound, in any material.

You ought to know the actual content of what is being used.

Mr. Gates: The paper and discussion has established in my mind one fact clearly, viz., that it is easier to get a dunt than to get a definition. It seems to be a question whether it goes through the body or only part of the way. My definition of a dunt, and I have had more experience in this line perhaps than many of you, is that it is a matter which brings extremely strained relations between the buyer and the manufacturer.

Mr. Hull: I think it would be a benefit to those of us not perfectly familiar with pottery terms, if this term should be as closely defined as possible in this connection.

Mr. Weelans: I do not know whether I can explain it to the satisfaction of the members. We, in the pottery business, consider a dunt something which happens very suddenly, which happens on the outside and goes all the way through, whereas, a crack starts sometimes and will not go through the piece. In other words, an explosion takes place in the ware and the fracture shows a glassy surface, whereas the ordinary fracture shows a rough surface. I think if a sample were broken open, it would show the difference. A dunt is something which takes place very suddenly, whereas a crack comes slowly. When I say suddenly, I do not really mean instantaneously. The fact is, I think, it starts some time before the break occurs, though we cannot see it until the fracture reaches the outside. It has been working, in my judgment, from the time it started in the clay.

Mr. Gates: Don't it always occur in cooling?

Mr. Weelans: During sudden changes of temperature.

Mr. Gates: Always after the highest heat?

Mr. Weelans: Yes, sir.

Mr. Binns: It always occurs in burnt ware. A clay crack may start a dunt. In invariably occurs on heating, cooling, or standing in the warehouse. It is evidence of a

high co-efficient and the fact that the equilibrium of the parts is disturbed or not properly adjusted.

Mr. Stover: When I saw the subject, I went to the scrap pile and found some pieces illustrating it. One particular piece did not dunt in the cooling, for it had started to dunt partly and the glaze had flowed into the opening. It did not go all the way through. I took out a piece of the center and demonstrated that a portion of the dunt had been filled with the glaze running in. So that piece had started to dunt during the raising of the heat.

Mr. Gates: That would be an interesting specimen to see and especially interesting to me. My idea has been that it occurs in the cooling, otherwise the glaze would melt over the dunt.

Mr. Booth: Probably all terra cotta men know that if we take a piece of terra cotta which is probably not of the right color, re-spray and reburn it, without any glaze, it will invariably crack in the second fire, with hair lines or dunts over it. Even when extra precautions are taken, and we start the kiln slower than for green stuff and when finished stop up the fire holes and retard the cooling, even then the same thing will happen almost nine times out of ten. If broken with the hammer, it will be found that the cracks go through clean, as some of these Mr. Weelans has shown.

Mr. Watts: Though it is probably not properly classed as a dunt, I have been forcibly impressed with a similar condition in handling glass insulators. Probably not many of you here have been brought in as close touch with the manufacture of glass insulators as I have, because I handled them in connection with porcelain. They are invariably made very heavy, and today they have almost gone into disuse because they dunt. I think perhaps that is as good a word as the glass men can find to express the condition. All the money you can ask has been spent on carefully working the material and as carefully cooling it, being as careful in thoroughly annealing it as possible. But they may be out on a line for five years, perhaps,

when suddenly on a bright day, when there has not been a rain for a month and the temperature has gone slowly up and down, it will go to pieces all at once. The glass men say they do not know what the trouble is. Glass has been made a chemical study longer than our part of the silicate industry, yet they cannot find a solution for it. As far as I have been able to locate it, it occurs in what we call hard glasses, glasses in which are potash and lime. It is very seldom found in a lead glass. However, lead glass is useless for our work, since it is attacked in a little while by the gases of the air and the surface becomes pitted so that it cannot be used for insulating. All the hard glasses are subject to the same thing and there seems to be no way to overcome it. It looks as if the glass man had exactly the same proportion as the sanitary ware manufacturer in this phenomenon of dunting, and perhaps the solution of the problem by the potter may mean its solution for the glass manufacturer as well. I am sure the latter would welcome it.

Mr. Conkling: This paper and discussion has been very interesting. This so-called dunting is one of the most serious factors we have to contend with. If it could be overcome in the manufacture of terra cotta, the business would be much more profitable.

Mr. Gates: Before this subject is dropped, I want timidly to advance a theory. My idea is that dunting is a question of temperature, and, after reaching the highest point, a question of cooling, similar to the tempering of steel or glass. An illustration of the latter would be the glass lamp chimney. We all know how very breakable some are, flying all to pieces under conditions through which they have passed successfully many times. Then we know the kind the man throws all over the office floor to prove its good qualities so we will buy it. It shows a difference in the tempering of the same material. It is a question just how that tempering can be handled. We run across examples that puzzle us frequently, though we temper very carefully we still have the difficulty. I would like to know

whether others have learned more than I have as to whether this is not strictly a tempering condition.

Mr. Ashley: It seems to me that the cause of dunting in white earthenware is similar to the cause which makes saggers crack. Ware made with coarsely ground flint is more resistent than that made with finely ground flint. Some saggers are more resisting, made with coarsely ground grog than those with finely ground grog.

WHITEWARE POSSIBILITIES OF COLORADO RAW MATERIALS.

BY

S. GEIJSBEEK, Seattle, Wash.

In the establishment of new industries, raw materials play a very important part. In the iron and steel industries it has so far been found advantageous to transport the ore and other raw materials to the place of manufacture. In the smelting of ores for values the large smelters are being concentrated closer and closer to the mines.

In the clay industries we find that plants which are using a large quantity of clay for their manufacturing processes are located close or not very far distant from the sources of their raw materials. When we come to the finer products of the clay industries, this difference of distance does not play an important part. It is usually a matter in which raw materials are not at all concerned which settles the point of location of such plants. In this country we find two distinct potting centers besides the scattered outside potteries. It can be stated on excellent authority that the outside potteries have been very successful in their operations, in fact more so than the manufacturers who are located in the potting centers will admit. Whatever may be the cause of this success, we will not discuss, nor is this the scope of this paper; it is enough to state that freight rates and manufacturing facilities play a very important parts, while raw materials have nothing to do with this question.

The raw materials which the potteries are using, are obtained from different states, New Jersey, Pennsylvania, Florida, North Carolina, Georgia, Tennessee, as well as from Canada and a few other localities, mostly from territory which lies east of the Mississippi river. In that territory, the freight charges on raw materials are not excessive and the cost of production can be held low enough

FIG. 3. The first plant to manufacture white ware in Colorado.

FIG. 4. A clay mine among the foot-hills.

to make the margin of profit a safe one. The whiteware potteries located within this territory have therefore a large choice in regard to their raw materials, but, should a new pottery be located west of this territory, a we must look for new deposits of raw materials, as freight rates are too high to ship greater distances. The western states the therefore more or less dependent upon their own resources. The question of raw materials for the manufacture of whiteware was carefully investigated by me some years ago for the states of Colorado, Utah and Wyoming.

Before taking up this question proper, we will point out that an investigation of raw materials forms a strong argument for the technical side of the Ceramic industry.

Whiteware Raw Materials.

In the manufacture of whiteware bodies we are using materials which are known under trade-names, such as kaolins, china clays, ball clays, feldspars and flints.

Under the name of kaolins and china clays we find many brands of white-burning clays which are put on the market either in the crude or washed state.

By ball clays we mean clays which are of a plastic nature, burn preferably to a close dense body of either white or slightly yellow color.

Feldspar is mostly furnished to the trade in the ground state, which makes it very hard to distinguish its nature. It may be a feldspar high in potash and low in other fluxing ingredients; it may be rich in soda or lime, or it may be a combination of all fluxes; it can further be ground dry or wet, prepared from the crude raw material or from the calcined state.

As flint we obtain ground material and little attention is paid whether the same was obtained from silica sand or calcined quartz. It may also be either dry or wet ground.

It is therefore quite proper to call attention to the testing of raw materials which go to make whiteware bodies. If these raw materials are put on the market and sold

without any definition as to their composition, it cannot be expected that we can obtain an uniform product. We still find today a majority of our manufacturers who do not test their raw materials. Such manufacturers would fight any proposition as to a change of raw materials, whatever better qualities it may possess, for the sole reason that they do not know how to make the necessary changes in order to use this new material.

The point of fine grinding of feldspars and flints has been brought out more or less at each meeting of this Society. Such excellent illustrations as Burt, Mayer and Binns have given go to show that the fineness of raw materials is a very important factor in the manufacture of whiteware bodies. W. Jackson has done good work in the English Society on that subject, and as the manufacturers will become more and more interested in this matter, the dealers in raw materials will give us more uniform products.

It may be assumed that on an average nearly every manufacturer will try to employ as near as possible the same raw materials which his successful neighbor is using. It has been found, however, that even this close imitation does not always produce the desired results and the interested parties are at a loss to account for this. It would be found upon close investigation that the successful neighbor was using his material according to its chemical and technical composition and that his success was not as much due to the raw materials which he used as to the skill with which he compounded them according to technical principles.

If, therefore, we go into a new territory and endeavor to find and use new raw materials of which we do not know anything, we must first examine these raw materials very carefully and determine their value.

Whiteware Raw Materials of Colorado.

Along the eastern front of the Rocky Mountains is a range of mountain slopes and foot hills. In the mountain

FIG. 5. Drift mining for fire clay and kaolin near Golden.

slopes we find the quartz and feldspar veins, while in the foot hills are clays.

Feldspar and Quartz. In the mountain slopes of the Colorado range we find well defined veins of orthoclase and quartzite. These veins are found in the Pre-Cambrian granites and are exposed in several places. In Platte Canyon and Clear Creek Canyon we find several dykes which have very pure quartz, while the feldspar is more or less intermingled with quartz streaks.

The developed deposits are found in Golden Gate Canyon about seven miles west of Golden. Here we find a deposit which has been worked for years for quartz which is shipped to the smelters in Denver. The feldspar had been disregarded up to the time of my investigation, and was exposed for several hundred feet. The outcroppings of the vein are highly stained with iron, but the quality improves with depth, and the feldspar found at the bottom of the open pit was as free from iron as could be expected. This feldspar is of a light grayish yellow color and has a well defined crystalline cleavage. The chemical analysis of this material is as follows:

Silica	65.33
Alumina	20.63
Ferric oxide	.32
Lime	2.05
Magnesia	.66
Potash	5.28
Soda	6.11
	100.38

Melted at a cone 8 heat, it gave a well fused, white glass.

About two miles north of this deposit we find another quartz and feldspar vein which is highly impregnated with mica. In fact, the mica is so prominent that this deposit is worked exclusively for that purpose. The feldspar is more or less decomposed. At first sight, it was thought to be highly stained with iron on account of its rose color,

but burning tests showed that it was of a pure quality and is so-called rose spar. This decomposed spar has not been leached sufficiently to carry off the alkalies and leave a kaolin deposit. In some places where the workings have been exposed for some years, this material is fairly plastic. In chemical composition it does not vary very much from the above sample, and its fusion point is somewhat lower.

There are several other localities from which we obtained samples, but inasmuch as most of these deposits had not been worked to any extent and some are mere prospects, it was found advisable to use for our purposes feldspar from the above deposits.

Kaolins and Clays. Along the foothills of this Colorado Range, extending along the eastern base, we find a great series of interbedded shales, sands and limestones of Jurassic and Cretaceous age. The beds are tilted at a high angle. The Jurassic rocks contain some shale which had not been used so far. The Cretaceous beds which overlie the Jurassic, consist of the following divisions:

1. The Dakota shales and sandstones;
2. The Benton shales and limestones;
3. The Niobrara limestones;
4. The Pierre shales;
5. The Fox Hill shales;
6. The Laramie shales;
7. The Arapahoe shales and sandstones.

The Dakota formation consists of shales and sandstones. The shales are frequently arenaceous and contain enough vegetable matter to make them brown and black. The Benton group carries large quantities of shales which have been worked to some extent, while the Pierre and Fox Hill shales have been worked quite heavily. The Laramie and Arapahoe clays are worked also to a large extent.

The principal clay formations of these foothills which are worked extensively we find in the so-called "Denver Basin," with Golden as the center. The hogbacks raise with their lofty peaks far above the plains, and it is in

FIG. 6. Opening out a clay stratum in the Dakota formation, where it is tilted up to a vertical position.

these hogbacks that we find the principal Dakota formation and its clays.

The mining of these clays is carried on somewhat differently than is customary, on account of the great dip of the veins. We also find numerous faults. The walls are sandstone and by proper propping the mines are kept open. The walls show distinctly, at numerous places, that these sandstones were formerly marine beds by their rippled appearance.

This Dakota formation is very interesting to the clay-worker. The principal vein is a black fire clay, of highly refractory quality, known as the Denver fire clay vein. This clay is used by the Denver Fire Clay Co. of Denver for its assayer's supplies. Its chemical composition is:

Silica	50.35
Alumina	33.64
Ferric oxide	0.75
Titanic acid	0.80
Lime	.....
Magnesia	trace
Potash	0.49
Soda	0.09
Chemical water, and loss on ignition	13.88
	100.00

It burns at a cone 10 heat to a light gray color, with some iron spots.

Against the east wall of this fireclay deposit we find in a few places a four to six-inch vein of highly plastic kaolin, sometimes impregnated with crystals of iron pyrites.

The rational analysis of the kaolin showed 99% clay substance. At a cone 10 heat it burns to a white, pure, open body.

To the west of these veins, in the same geological formation, we find another vein of dark brown clay known as the Golden pottery vein. When mined, this clay is very hard, but weathers very easily, and works up to a plastic body.

Its rational analysis is:

Clay substance	48.25	per cent.
Spar	0.65	"
Quartz	51.65	"

Burnt at cone 10 it gives a white, open body of good color.

In the Benton formation we find some excellent stoneware clays, of which the principal vein is known as the Queen City vein.

In the Pierre, Fox Hill, Laramie and Arapahoe formations we find excellent clays which are used for brick and sewer pipe manufacture.

Whiteware Manufacture.

Having outlined in this brief description the principal clay deposits of central Colorado, we will take up the matter of using these materials which were found suitable for the manufacture of whiteware.

The feldspars found were carefully selected, analyzed, calcined, ground and tests made. These tests showed that this material was as good as eastern spar. The quartz was calcined and ground, and used as flint. However, later on we changed from quartz to silica sand for flint purposes. In the small vein of kaolin we had a product which was pure white in color, and plastic in nature. The main question was what could be substituted for the ball clays of the East. The clay known as the Golden pottery vein was selected to fill that place on account of its white burning qualities. However, to use a clay which runs as high in silica as 52%, by rational analysis, for such purposes was a bold proposition, but experiments and samples made soon showed that it was feasible. The body mixtures made produced excellent ware, and while its color was not as good as that of some of the eastern whiteware, it did give a good grade of ware, which could be disposed of without any difficulty.

In carrying the experiments along this line we were

FIG. 7. Showing the system of mining the Denver fire clay. The stratum, originally horizontal, has been tilted to the vertical during the uplift of the Rocky Mountains, and the vein is now worked on edge. The kaolin occurs on one wall of this cut.

guided by practice in vogue in several places in Germany. The composition of whiteware bodies found in different localities does not vary materially. Their average composition is:

Clay substance	40-65 per cent.
Feldspar	14- 7 "
Flint	46-28 "

In using the raw materials found in Colorado we could not employ as much kaolin as is used generally, because the deposit was small. Of the white burning Golden pottery clay there was an abundance at hand, so we compounded a body accordingly, and pieces of ware which I have here, run in composition as follows:

Clay substance	42 per cent.
Feldspar	9 "
Flint	49 "

The biscuit ware was fired at cone 8 and the glaze matured at cone 06. As a matter of record it might be stated that this ware was fired in downdraft kilns, both for biscuit and glost.

In the establishment of such an industry we not only must look for the raw materials which are the main issue, but the clays used for the accessories in pottery work must also be considered. We found fire clay of excellent quality and there was also a good plastic stoneware clay. Calcined clay from the coal mine waste was used for grog to start with.

The fuel question is no more complicated than in the eastern states, and good coal can be had from several mines. The lignite from the Northern Colorado coal field gives an excellent coal for the first part of the burn, while the hard coal of the southern field is a good fuel for finishing the burning. For the glost burn, lignite was used exclusively.

Conclusions.

The possibilities of manufacturing whiteware from Colorado raw materials are good. There is no question but that such a proposition can be handled successfully. An eastern manufacturer, who is used to his English china clay, his English ball clay, his Cornwall stone, ground flint and spar which he buys in carload lots, should never attempt to go into business in that part of the country if his chemical and technical knowledge is limited. He is sure to fail in the manufacturing part. To use Colorado raw materials, the manufacturer should know not only how to handle his clays, spars and flint, but he should know how to prepare the same.

So much for the technical side of the question. The commercial side of the whiteware industry, as far as Colorado is concerned, is also good. All facts tend to show that with sufficient capital such an industry will be a success. However, there is one thing which every one who goes west, and especially to Colorado, should bear in mind, and this is, that Colorado is not a manufacturing state. There, where every man, woman and child is interested in the great gamble of gold and silver mining, carrying with it schemes which swallow millions of dollars yearly, without a penny in return, a legitimate business which only offers a return of a reasonable per cent. on the investment, and which needs a few thousand dollars in order to make it a financial success had hard work to capitalize under existing conditions.

DISCUSSION.

Mr. Geijsbeek: This (exhibiting cup) is the first cup made in Golden, and this is the first saucer ever turned out. On the bottom you will find the record, signed by my wife. It has been standing in a cellar for three or four years, but was not crazed when it was put there. It now shows some crazing on the saucer, but the cup is practically free from crazing. I brought it to show what could

be done with those clays. These were the first articles made after we got started, without any of the improvements which were added later. Beside this I found a biscuit cup, and my wife had another one which she had been constantly using in the household. This (indicating) is a body crack from using. It has been in use, while this is a biscuit piece of the same composition. I have also a little tile here.

Mr. Booth: Is that factory running yet?

Mr. Geijsbeek: No.

The Chair Mr. Geijsbeek has given us an interesting paper, which is now open for discussion.

Mr. Ashley: I will ask if that body showed much tendency to dunting?

Mr. Geijsbeek: No, it did not.

THE COST OF POTTERY MANUFACTURE IN THE GREEN ROOM STAGE.

BY

GEO. SIMCOE, Victor, N. Y.

An analysis of the above proposition is, to say the least, an interesting and instructive one, calculated to cover the field that is even darkest in the brightest places. Who is to prepare for us a scientifically compiled table showing the curvature, thickness, relative weight, etc.? I mean such a table as you find the iron workers using. You find nothing that gives you any degree of satisfaction, but in place of such a table you find green room foremen sailing round with a profile in one hand and a file in the other, vibrating between some jiggermen he has chosen as his prey and the machine shop, filing the profile down a shade or a fraction as they intelligently express it, then repairing to the jiggerman, who is always in a hurry and can seldom be found in the humor for such work. This leads us up to the point where I may advance a pet theory of mine which I state as follows: Have a laboratory in connection with your green room foreman's office equipped with jigger, finishing whirler, hot closet, provided with thermometer, also a vise and files. This outfit will enable the foreman to work the scheme of manufacture of a certain article out to his own satisfaction and thus be enabled to take the molds and tools to the proper jiggerman and say how he wants the ware made, thus doing away with the unpleasantness of having the jiggerman do the experimenting. This to my mind is a practical approach to reducing the particular pottery conditions to a scientific basis. I have mentioned this feature first as it is the primary vital secret to reduction in green room loss, for you can see on the face of it that after the ware has been properly modeled, if the profile which forms the in or outside of the ware, as the case may be, is not made so as

to produce the desired conformation with the shape as well as re-enforce the points of greatest strain, you are going to have green room loss.

The second condition that should be looked after most carefully is the supervision of the clay pugging. The selection of a capable and trustworthy man to do this work is often neglected and with disastrous results. Further, the green room foreman should oversee the clay pugger and order such variations in tempering as his judgment warrants. I will not dwell upon this point, but desire to point out that a jiggerman, who receives clay in all conditions from soft to stiff, is liable to make ware that will crack and, further, the inequalities in thickness will be worse than cracks, for, when a piece of ware is cracked it is thrown out, while uneven ware may go through the kiln and on to the market and act as a reflex advertisement for the manufacturer. So much for the pugging and the important part it plays. Now as to the actual cost of manufacture in the green state you have but to refer to the uniform price list which was adopted by the eastern operative potters in November, 1904, subject to correction, and note the prices adjusted for local conditions and special shapes. In passing I wish to touch upon a point that is shattering to the ideals of progressive potting, i. e., when the uniform price list was adopted, it gave the makers of festoon ware an increase, while the makers of plain edge were decreased in most instances. This increase and decrease amounted to something like 10%. Now what did our boss potters do but hire a modeler and proceed to get the same embossed effect by using a plain edge. Now this I consider a sweat shop method that should be thrown out by us as altogether intolerable and not to be countenanced by men who look for the realization of high excellence in American pottery. Do not mistake my meaning and think that I preach impractical idealism; nothing would be farther from my mind. When you wish to cut down your cost of manufacture, do it in the right place and not where it will hinder growth and get you down on a level with a

nailmaker who will put six barbs on one nail and seven on another.

We come now to a very important feature in the green manufacture, viz., the apportioning of ware to be made on the jigger on one hand and wet or dry pressed on the other. To make this demarcation requires a great deal of practical knowledge and good judgment. As a general rule the wet pressed ware is the best, for in this process the operator has more chance to humor his clay and this factor, in the nature of the case, decreases the liability to crack. As I heard an old potter say once, "Clay is like human nature, rub it the wrong way and it will get back at you, but humor it and you have smooth sailing." No better formula for the guidance of the operative potter could be propounded than this. The dry pressing as applied to general ware is a very small field, such as bone dishes, individual butters and the smaller sizes of bakers. The ware thus made losses its clear ring and has a punky sound, It also falls several per cent. lower in the abrasion and absorbing tests.

The jiggering or jollying process as applied to the manufacture of ware covers such shapes as are round and some oval shapes for large orders. Ewers and like hollow-ware not having too large a belly may be so made. Otherwise it is much better to make them by the wet pressing process. The chief feature to observe in handling all these branches is to have one foreman who has the say as to the thickness of the ware manufactured and all operatives in these branches should know no other dictator than this foreman. It is an exceedingly trying and discouraging proposition for men to suit the caprice of three or four bosses, each varying in his idea of the proper thickness.

Now, when these several operators know exactly what is desired it is up to the management to carry out their scheme. This done, we are brought to the finishing, which is unquestionably the most important of this department. Good results are only obtained by eternal vigilance and enforcing of requirements, in other words a most rigid

discipline should be enforced right at this point, for the opportunity and tendency to slight the work is enormous.

The next point is taking care of this stock, in other words the green stock room. Some of our modern potteries are so constructed that they may carry the ware from the making department to the green ware room on one floor. This is the ideal way and the shorter the carry the better, but where you have to carry down one or two flights of stairs there is liability of losing a great deal of ware. Go into the average pottery and see the jiggermen start to carry the ware out after it has been counted out, and observe them carry a board of flat ware down stairs, and you would not be surprised at the size of your biscuit scrap pile.

In the preceding I have the vital points of leakage in the green manufacture and the remedy is obvious.

Through the kindness of Mr. Ernest Mayer I can place before you a table that will furnish the fundamentals for green room cost figuring, showing the amount of clay, white hard, in the several articles mentioned, the making cost, also the blocking and casing of moulds, together with the mould making cost. I have endeavored to cover in a general way the whiteware products in the selection of this list. I shall not go into details and take up time and space with a lot of detailed data. Make your moulds as best you may under journeymen, apprentices or by the day. The same holds good of the other expenses. If you are in a union labor zone, you have your troubles. Where your labor is unorganized, you may be able to manufacture cheaper, though in this instance you may loose in speed and skill.

And now in conclusion I refer you to my table which may be used as a starting point when figuring our green room manufacturing cost.

Article.	Weight of clay, white hard, in dozens.	Making cost per dozen.	Blocking.	Casing.	Mould making.
Bakers 2½	46.0 oz.	$ .09	$ .30	$ .30	$ .40 doz.
" 3	54.6	.09	.30	.30	.40 "
" 6	117.7	.12	.30	.30	.40 "
" 7	135.9	.13	.30	.30	.65 "
" 8	188.3	.15	.30	.30	.60 "
Bone dishes	44.9	.14			.70 "
Bowls 30s	118.8	.055	.50	.50	.45 "
" 36s	84.0	.05	.50	.50	.45 "
" oyster	85.6	.035	.50	.50	.45 "
Butter bottoms	114.5				
" covers	43.9	.16	1.70	1.70	.55 each
" drainers	31.6				
Ind. butters	15.5	.02¾	.34	.34	.25 doz.
Cake plates	209.7	.08			.10 each
Casserole bot. 9	321.6				
" cov. 9	318.9	1.20	2.40	2.40	.75 "
" bot. 7	281.4				
" cov. 7	183.0	.97	2.40	2.40	.75 "
Coffee cups	80.8	.07¼	.35	.35	.40 doz.
" saucers	52.3	.02¾	.35	.35	.30 "
H. D. H. coffee cups	19.4	.05½	.35	.35	.35 "
H. D. H. " saucers.	35.1	.02¾	.35	.35	.30 "
Cov. dish bot. 7	140.8				
" cov. 7	134.8	1.01	2.40	2.40	.75 each
" bot. 8	276.1				
" cov. 8	169.1	1.11	2.40	2.40	.75 "
Dishes 3	54.6	.09	.30	.30	.40 doz.
" 4	81.6	.10	.30	.30	.40 "
" 6	153.0	.12	.30	.30	.40 "
" 8	223.1	.15	.30	.30	.65 "
" 10	382.0	.18	.30	.30	.75 "
" 12	547.8	.22	.30	.30	.75 "
" 14	853.9	.29	.45	.45	1.40 "
Fruits 4	43.1	.02¾	.35	.35	.30 "
" 4½	56.4	.02¾	.35	.35	.30 "
" 5	78.4	.02¾	.35	.35	.30 "
Jugs 6	585.3	.23	1.90	1.90	.55 each
" 12	471.9	.18	1.90	1.90	.45 "
" 24	318.9	.15	1.35	1.35	.35 "
" 30	266.4	.13	1.35	1.35	.35 "
" 36	256.8	.11	1.35	1.35	.35 "
Nappies 6	119.8	.10	.50	.50	.65 doz.
" 7	194.7	.10	.50	.50	.65 "
" 8	246.1	.10	.50	.50	.65 "
Oatmeals	89.4	.05	.....	.....	.45 "
Pickles	108.1	.28	.30	.30	.70 "

Article.	Weight of clay, white hard, in dozens.	Making cost per dozen.	Blocking.	Casing.	Mould making.	
Plaltes pla. 4″	36.4	.03	.37½	.37½	.35	"
" " 5″	65.3	.03½	.37½	.37½	.40	"
" " 6″	103.8	.04	.37½	.37½	.40	"
" " 7″	152.5	.04½	.37½	.37½	.45	"
" " 8″	206.5	.05¼	.37½	.37½	.45	"
" " 7″ deep	159.0	.05½	.37½	.37½	.45	"
Sauce boats	122.0	.42	1.50	1.50	.45	each
Salads	299.1	.75	1.05	1.05	.45	"
Sauce tureen bot.	115.6					
" " cov.	61.0	1.00	2.40	2.40	.75	"
" " stand	111.3	.33	.....	.....	.....	
" " ladle	34.2	.25	.85	.85	.15	"
Sugar bot. 30s	164.2					
" cov. 30s	61.0	1.00	2.40	2.40	.75	"
Teapot bot. 24s	301.2					
" cov. 24s	48.7	.25	2.65	2.65	.95	"
Tea cups	54.0	.07¼	.35	.35	.40	doz.
" saucers	64.2	.02¾	.35	.35	.30	"
Ewers 9s	844.2	.60	2.05	2.05	.70	"
Basins 9s	896.7	.25	.50	.50	1.75	"
Chambers bot. 9s	540.4					
" cov. 9s	277.1	.25	1.05	1.05	1.25	"
Mouth ewers	237.5	.18	2.05	2.05	.50	"
Brush vases	129.5	.06	.....	.....	.35	each
Soap bottoms	145.0					
" covers	91.0	.18	1.90	1.90	.50	"
" drainers	32.9					
Mugs 3s	101.1	.03½	1.30	1.30	.30	"
Slop jar bot	1297.4					
" cover	145.5	.90	2.60	2.60	1.65	"

DISCUSSION.

Mr. Watts: I would like to state that Mr. Simcoe is putting these ideas into actual operation in his new position as Superintendent of Plant No. 2 of the Locke Insulator Manufacturing Company. He will have a process room, thoroughly equipped, with a competent workman always on hand to carry the process through from beginning to end, so that he will have what he describes here as a thoroughly equipped experimental room. There will also be a thoroughly equipped laboratory.

SEGER PORCELAIN WITH MATERIALS ACCESSIBLE TO AMERICAN POTTERS.

BY

C. E. JACKSON, Syracuse, N. Y.

It was the object of the following work to see what results could be gotten with plastic American kaolins combined with non-plastic or slightly plastic English kaolins, when made into porcelains, by the methods used in the production of the hard fired, German, true porcelain. The so-called true porcelain is made by low fire biscuit and hard glost firing, which is just the reverse of the American or English process, viz., hard biscuit and easy or semi-easy glost firing. In either case, the end in view is the same, i. e., the production of a translucent vitreous body. It is not my purpose to discuss the relative merits of these two processes at this time. The article which inspired this investigation may be found on p. 708, Vol. II, "Collected Writings of Herman A. Seger."

Neglecting everything in this article until the composition of the Seger porcelain is reached, we come to the composition which Dr. Seger recommends, viz., clay substance 25%, feldspar 30%, quartz 45%. In making Seger porcelain, the proportion of clays, feldspar and flint vary only in so far as may be necessary to meet the above formula. The three clays used by Dr. Seger, viz., the Lothain clay, and the kaolins of Sennewitz and Zettlitz, vary in their proportion of clay substance. The Lothain clay is a plastic clay, practically a ball clay, of the composition: Clay substance 81%, quartz 19%. I know of only two American clays which, from a commercial or technical standpoint, could be used as the plastic ingredients for this work, viz., the Florida and Georgia kaolins. Not knowing which was the better of these two for this work, I decided to compare one against the other, making two mixings of each number in the series, in one of which the Georgia kaolin is used as the plastic clay, and in the other, the Florida kaolin.

According to analyses given by their distributors, both of these kaolins contain a very high content of clay substance, Georgia clay containing 99%. In comparing these plastic clays with Lothain clay, a noticeable difference in their clay substance is apparent.

In some previous experimental work, I had made a very good vitreous porcelain, which was semi-translucent, even when made up in regulation hotel thickness, at cone 8. I therefore adopted this formula as one extreme of the present series. In that body, I had used 50% clay content, at cone 8, and having succeeded so well with it, I was afraid to run the other extreme down so low as 25%, especially as I was intending to fire so much harder than I had done before. I therefore took 30% clay substance as the low extreme. The raw materials used were as follows:

Georgia kaolin, from Mr. John Sant, East Liverpool, Ohio.

Florida kaolin, from the American Potters' Supply Co., Baltimore, Md.

English china clay, from Hammill & Gillespie,, New York, N. Y.

Feldspar, from the Maine Feldspar Co., Augusta, Me.

Flint, from the Potters' Milling Co., East Liverpool, Ohio.

Analyses of Clays Used.

	Per cent. Clay Substance.	Per cent Feldspathic Matter.	Per cent. Quartz.
Georgia Kaolin	99.00	.....	1.00
Florida Kaolin	98.00	.....	2.00
English China Clay	94.25	4.69	1.26

Using these materials I compounded the following series of porcelain bodies:

Percentage Composition of the Series.

No.	Per cent. Clay Subst. Georgia.	Per cent. Clay Subst. Florida.	Per cent. Clay Subst. English China Clay.	Per cent. Spar.	Per cent. Whiting.	Per cent. Flint.	Per cent. total Clay Substance.	Per cent. Total Spar.	Per cent. Total Flint.
A-1	19.8	.....	9.4	30.4	.....	40.2	29.2	30.2	40.2
A-2	.....	19.6	9.4	30.4	.....	40.4	29.0	30.4	40.4
B-1	19.8	.....	14.1	28.2	.....	37.8	33.9	28.2	37.8
B-2	.....	19.6	14.1	28.2	.....	38.0	33.7	28.2	38.0
C-1	19.8	.....	19.8	25.9	.....	35.4	39.6	25.9	35.4
C-2	.....	19.6	19.8	25.9	.....	35.6	39.4	25.9	35.6
D-1	19.8	.....	23.5	23.6	.....	33.0	43.3	23.6	33.0
D-2	.....	19.6	23.5	23.6	.....	33.2	43.1	23.6	33.2
E-1	19.8	.....	28.2	21.4	.....	30.5	48.0	21.4	30.5
E-2	.....	19.6	28.2	21.4	.....	30.7	47.8	21.4	30.7
F-1	19.8	.....	28.2	19.4	2.0	30.5	48.0	19.4	30.5
F-2	.....	19.6	28.2	19.4	2.0	30.7	47.8	19.4	30.7

In the foregoing series we have an increasing clay substance, brought about by steady additions of English china clay, the plastic clays remaining the same throughout. The feldspar content decreases until in the last two of the series a replacement of feldspar takes place by two per cent. of calcium carbonate. The silica content decreases until E-1 and F-1 contain the same amount.

Mixing and Manufacture of Test Pieces.

Since the work was undertaken hastily and had to be completed within a specified time, many obstacles had to

be overcome which would militate against the production of anything other than the simplest articles. The object was to arrive at certain technical, rather than artistic results; hence small cups only were made as trial pieces. Each body was made up by itself, thus making twelve mixings. Each was ground in a small pebble mill for one hour, the object being to mix, rather than grind. Each mixing was screened through a 120 mesh screen, allowed to stand 24 hours, decanted, and cast into small cups. Some difficulty from plasticity was met at this point, as each succeeding number of the series became more plastic and therefore more difficult to cast. No trouble was experienced until C-1 was reached; from this point on, ½ oz. of sal-soda was added for every 10 lbs. of dry material, the soda being pulverized, and then dissolved in water. No trouble was met after recourse to this method. While no effort was made to demonstrate the fact, I firmly believe that any body in the series could be used, as far as the plasticity is concerned, for throwing, turning, jiggering and pressing, but only after the workmen employed had gained some experience in handling it.

Firing the Biscuit.

The kiln employed for firing the trials was a small updraft kiln holding about six cup saggers and was fired by natural gas. The cups were placed in the cup saggers and fired to cone 1 for their first fire, after which they were dipped in the glaze composed of the mixture from which cone No. 4 of the Seger series is made. The formula is:

$$\left.\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\} 0.5\ Al_2O_3 \left\{ 4.00\ SiO_2 \right.$$

Firing Glost.

The cups were then placed in saggers, and fired to cone 10, which cone Dr. Seger used as his maximum. Trials at cone 8 showed the glaze to be in a semi-fused con-

dition. At cone 9, the glaze began to come bright, and at cone 10 the trials drawn showed the glaze well matured. The firing was then stopped, as the A-1 and A-2 trials drawn showed evidence of becoming soft, and I feared the cups would sink. The time of firing was twenty-six and one-half hours. No effort was made to get a better color by the use of reducing conditions at any stage of the firing.

Results.

We will discuss the results obtained under the following headings: *First,* color, individually and relatively, *second,* translucency, and *third,* general observations.

First. The color of the series throughout is cream white. Since reducing conditions were practically absent, this was to be expected. The amount of color depended on the amount of iron brought in by the plastic clays and other materials. With reference to the two plastic clays used, the porcelain produced from each shows the same cream white color, and one cannot be distinguished from the other in the same series. The ivory or cream white color lends itself nicely to beautiful decoration for ornamental porcelain.

Second. Beginning with A-1 and A-2 in the series, the translucency is equal to that of any porcelain available for comparison. From A-1 and A-2, the influence of an increasing clay content is plainly to be seen. The translucency diminishes as the clay content increases until F-1 and F-2 is reached. Here the translucency is greater than in the D. or E. series, showing the effect of a 2% replacement of feldspar by whiting, without in any way impairing the color.

Third. The bodies throughout the entire series are vitreous, and show a shining, glassy fracture. Had we gone to cone 11 or 12, we believe we should have had a better series, as the trials drawn at cone 10 were in a measure deceptive, since no piece left in the kiln showed any signs of malformation due to over-firing.

Summary.

A true porcelain can be made between cone 10 and 12 with American clays as the plastic ingredient and with American spar and flint as they are now sold on the market. Any of the series tested will give a good, hard translucent porcelain of ivory color. The one selected would virtually depend on the purpose for which it is to be used.

DISCUSSION.

Mr. Ogden: There is one point which appeals to me particularly, and that is the marked difference in the F series, where a small amount of whiting makes such a vast difference in the behavior of the body as to translucency. I think Mr. Watts called attention to that in his paper, and I think reference was made to it in my own paper on porcelain.

Mr. Stover: Have there been any trials made as to the brittleness of this porcelain as compared with others?

Mr. Jackson: No, this was not looked into.

Mr. Orton: Is it your idea that this opens a practical line for commercial manufacture, or as Seger originally put it, for decorative porcelain, but not for commercial products?

Mr. Jackson: He makes that point with reference to low alumina porcelain. eH says for industrial use it is practically useless, owing to the lower alumina content. I started with a higher percent of clay content and carried a higher percent all the way through and with two percent of whiting it gave good translucency. F-1 and F-2 would make very good service porcelain.

Mr. Burt: Why are you not passing from Seger porcelain into true porcelain?

Mr. Jackson: We are.

Mr. Orton: In going to cone 10, are you not getting out of the Seger porcelain group? Was it not his idea that he had there a body firing at a lower temperature?

Mr. Jackson: Yes; at cone eight. This was under

sharp fire. I do not consider that I exceeded his temperature under other conditions.

Mr. Burt: It has passed out of the Seger series?

Mr. Jackson: Yes, sir; certainly.

Mr. Stover: I will ask Professor Orton whether he considers the rattler process the best way of testing the relative toughness of bodies. In the use of hotel china, they consider the quality of wear the most important, that which will stand the roughest usage is the best, and much of this cheap German porcelain coming on the market would not stand it at all. Is this method a good method for comparison?

Mr. Orton: It never occurred to me to buy a dishwashing machine to test relative toughness. I think the dishwasher does what the rattler does. The rattler is the only thing we have devised for getting at the relative toughness. I do not know of any other. We can judge the relative hardness by other methods, also the tensile strength, crushing strength, etc.; but when it comes to the peculiar quality of toughness, I do not know of any other device by which we can get at it except some form of the abrasion or rattler process. While it was originally designed to test paving brick, it has been used for testing all sort of material. The conditions of the test must, of course, be adjusted to the work in hand. We can make the ball-mill test so severe as to pulverize the material to powder; or so light as to scarcely do any harm at all. I should judge the dishwashing machines would represent the minimum wear.

In my school, I give out several different sort of wares and let the student standarize the ball mill or rattler for the kind of ware. I sent some of the boys down into the city at one time to buy a half dozen Haviland plates and a similar quantity of American porcelain plates in the open market. They were smashed up into small pieces of about 1 to 2 square inches area, and rattled under exactly comparable conditions. We found the French plates lost three times as much as those of American manufacture,

every condition being uniform. In the same way we test floor tiles, and we constantly test bricks of various sorts in that manner. I do not know of any other test which has been proposed for getting at that factor.

I understand Mr. L. W. Page, in the Road Material Laboratory at Washington, has built a machine for testing resistance of materials to impact, a machine which lifts a weight and drops it, constantly increasing the height of each blow until the test piece breaks. This machine is very small, but he told me he was devising a larger machine on the same general plan, with which he hoped to be able to test larger pieces. He thought the impact test, when fully developed, would give us, perhaps, a better measure of toughness than the rattler process. The rattler process is open to severe criticism, but it is practically the only thing available. If this impact machine does the work, it will very likely supplant the rattler. Perhaps, Dr. Cushman can tell us something about this.

Mr. Cushman: The large machine recently constructed by Mr. Page drops a 10 kilogram hammer from as great a heighth as a meter, and with it we can break a paving brick. We have not, however, gotten any systematic series of tests with it. The work done with it is testing macadam road materials, testing the hardness which we call resistance to abrasion. The impact of the caulks of the horse's feet represents the impact on the road surface and abrasion, with the rolling friction carrying sand and particles of rock over the surface and breaking up the surface of the road. Besides that we use the regular abrasion test for resistance to wear, which is the rattler test.

We have the three different results to test for, viz., hardness, toughness, and resistance to wear. It is rather interesting to look over a series of these three tests on rocks, because frequently it happens that a rock which is harder and tougher than another does not resist near so well. It is not necessarily a measure of hardness and toughness in that sense. Of course, the prob-

lem you have before you, getting a tough body that will resist chipping and breakage, is somewhat different. What you want is resistance to the very thing the dish-washer does, therefore, I think the rattler test is ideal for your purpose; but I do not think it is altogether ideal for paving brick tests, because paving bricks are not put to that sort of use. Paving bricks want an entirely different test, for attributes of a different character; therefore, I think the rattler test is open to criticism. I think the rattler test for this sort of material, properly modified, is the ideal test.

I wish some gentlemen of the Society who are interested in this problem of toughness would furnish us with some test pieces. We have the two and ten kilogram machine in working order. If we could get the test pieces there is nothing we would like better than to make the tests and turn the results over to the person interested in working them out. We would like to have test pieces of glazed and unglazed pieces to see what can be done with this impact machine. I think it would be interesting.

Mr. Orton: What size and shape of test pieces would you like?

Mr. Cushman: We are prepared to test any shape within certain limits, but I have never considered that matter. In the large machine we could test anything up to a whole paving brick, and can take any shape test piece. I have never thought about that, and think I should want advice about it from some of you. You know more about clay and clay burning than I do. Almost any kind of test piece considered most appropriate to the person interested could be tested, but I have no opinion as to what the shape or size should be.

Mr. Orton: It seems to me that here is a very practical suggestion along the line of Mr. Hice's talk this morning. We have this government bureau equipped with apparatus and an invitation to come and use it, and it would seem that the Society ought not to be slow in accepting an invitation of that kind.

Mr. Binns: I do not think Dr. Cushman need worry about not having material. I want to say a word with reference to Mr. Jackson's paper, in regard to the method of hard porcelain manufacture. I have always been a little skeptical of Seger's results in the matter of his porcelain, because I never have seen nor got a mixture made from the cone No. 4 formula which would fuse to a brilliant glaze at anything like cone 8. I always had to use cone twelve and never found a fine glaze below that. The biscuit fire which Mr. Jackson used is undoubtedly high, considering he had no concern with reducing action, though I don't know that this makes any difference. If we fire the biscuit as high as cone 1 we will not get any subsequent benefit from reducing action; 04 or 05 is the limit for biscuit baking, to be followed by a reducing fire. The iron becomes fixed above that and it is not possible to reduce it. In regard to the method of manufacture, I am very skeptical of the possibility of grafting the European method of hard porcelain manufacture upon American procedure. The best of our practical workmen are all trained along the English lines, and it would be an enormous undertaking to train a factory of hands to the soft-biscuit-hard-glaze manufacture. I do not think it is within reach of the practical potters without either a very considerable outlay in apparatus and training, or a very considerable importation of skilled workmen from Europe. Furthermore, I am skeptical as to the advantage of the method. I think the true solution of the china production lies in the direction of bone china, the English plan, rather than the porcelain of Germany. While the English china is a little more liable to fracture, the supreme disadvantage of French porcelain is its liability to chip. Hotel china is better than that, but its color and imperfect translucency are against it. That is unquestionably, in my opinion, the true outlet for our aspiration for true china. There is nothing on the face of the earth which beats for beauty the English bone china dinner plate. Why we should, for mere sentiment, strive after

German porcelain, I cannot see. If we can succeed with bone china along these English lines, we will do more to upset the foreign importation of French or German porcelain than in any other way.

KILNS FOR BURNING ARCHITECTURAL TERRA COTTA.

BY

I. L. CONKLING, Philadelphia.

The problem of the economical burning of architectural terra cotta is one difficult to solve. The great variety of shapes, sizes, finish and color constantly tends to upset the plans of the manufacturer and interferes with the smooth progress of the work. Our business is anything but a routine one. It is almost impossible to adjust the mixture of such a varied material to one burning temperature and, unless they are so adjusted, frequent interruptions are necessary. Often, when the shop is full of dry work, a partly filled kiln will have to wait several days until the ware then required is dry. Owing to this fact, it is advantageous to have kilns of various sizes, that is, a few small kilns varied in size. This is not economical from the fuel standpoint, as it costs more to burn in a small kiln. Figures bearing on this point will be given later.

Concerning the variety of color and finish, I will say that almost every manufacturer is trying to satisfy every whim of the architect, and they are very many

It is said that there are some who have their standard colors, and if the architects do not like what they have, they may go elsewhere and buy. We have not reached that state of independence.

Muffle vs. Open Kilns. — There are two important questions involved, the cost of fuel and repairs. Eliminating these, there is not much worth considering. How much more fuel does it take to burn a muffle than an open kiln? My opinion is that it requires very little more, but our experience with open kilns is limited. The only time we used this kiln was when we were making fire-flashed work. This was several years ago and I have no exact data to give, but I do know it took very little more coal of the kind which we always use.

We did not then use cones, nor instruments to test the temperature, but we must have burned the open kilns at a slightly higher temperature, as the clay used was a little more refractory than that for muffle work. As near as I can remember, it took about the same time and amount of coal. We used both up and down draft open kilns and I never noticed any difference in the coal consumed. One would naturally think it would take a great deal more fuel for a muffle kiln. If it does not, why not? My opinion is that the heat in passing around a muffle, is so absorbed by the muffle, and again taken up by the air and the objects in the kiln, that the amount of escaping heat is no greater when it passes to the outside than that which would pass off from an open kiln of equal size and temperature.

My reason for thinking so is, that certain tests made by us seemed to prove it. We put cones on top of the muffle crown and under the outer crown, near the opening in the center. In some cases the temperature in this flue was a little higher and in some cases, a little lower than that inside the muffle; not more than one cone lower or higher. In one test No. 8 cone went down within the muffle and No. 7 was the highest that went down in the flue. In another test, cone 8 went down within the muffle and 9 went down in the flue. The average temperature in the flue seems to have been about the same as that within the muffle. We do not know what effect the gases in the flue had on the cones, as to their fusibility.

The outer walls of a muffle kiln must take up a little more heat than they do in an open kiln, because the temperature in the lower part of the flues is greater than that which would exist in the same locality in an open kiln. Not counting this loss, and assuming that the escaping gases in both types are at the same temperature, and assuming that the same amount of coal is consumed in the same time, with the same conditions of combustion, (and I see no reason why the same condition should not exist) there would be no loss either way. It seems reasonable to suppose that the escaping heat from an up-draft open kiln

in the last stage of burning, must be about as high as that throughout the kiln. I admit, that if an open kiln were closely packed, in the early stage of firing, a greater percentage of heat would be taken up by the objects being burned, than would be taken up by a muffle surrounding the same bulk of material in the same time, at the same temperature and at the same stage of firing, but I doubt that the difference would be very great.

The cost of fuel per ton of terra cotta will be discussed in connection with sizes of kilns.

Up and Down Draft Kilns.

We have used both types of open kilns, but don't think we saved much fuel by the use of the down draft. Doubtless, there is a more even distribution of heat in the latter, but there certainly is a greater accummulation of gases in the down draft. We finally adopted this type for fire-flashed work, because we could flash the kilns more uniformly, demonstrating that the kiln was more thoroughly permeated with gases. This would seem more dangerous for a muffle kiln, where it is desired to be as free from gases as possible. If there are any openings in the muffle, the gas would be more apt to leak through.

As to the economy of fuel in a down draft muffle kiln, I cannot speak with authority. We have never used it, but it would seem, from the reasoning in connection with the open vs. muffle kiln, that there would be little, if any economy. If the escaping heat in an up-draft muffle kiln is not at a higher temperature than that within the muffle, I cannot see what the material gain is in sending it down again, either through a separate flue outside of the muffle, up through a center stack and out, or down through a center stack and up through flues in the outer wall or into an isolated stack. If the heat sent down is no greater than that in the kiln, it cannot add anything to it. It may be, that, if sent through a center stack, it would prevent a very slight coolness perceptible in the center of our kilns, and it may be, if sent up through the outer walls, it may help

to retain the heat. These are possible advantages, but I think they are fully offset by the more complex construction of a down draft muffle kiln and by the extra repairs necessary thereto.

You will notice that there is no center stack in our kilns and no draft under the floor. There is a little coolness in our bottom center.

Durability and Repairs.

This is where the terra cotta makers sustain the greatest loss in connection with kilns. We have tried many plans of construction, but find that what we are now using seems to be the best we have had. The most vital point is the support of the muffle in front of the fire chamber. Piers were formerly used for the support of the muffle and floor, but we now use practically semi-circular arches, beginning under the muffle in front of the fire chamber and running inward toward the center until they intersect each other. Inside of that, and also on the outside and between the arches, we use piers, see drawing.

The next weakest point is the inner arch over the fire chamber, and the next, the side lining of the fire chamber. The last two are more easily repaired. The trouble is, when the foundation of the muffle goes, it settles, opens, and lets the gases in the kiln. If we could get bricks that would stand in these parts, we could afford to pay almost any price for them. Any ordinary, good fire brick, will stand for a few burnings, but the best we can get, in a short time, become eaten and melted away. If the base of the muffle could remain intact, the superstructure would last many more times than it does.

I should have mentioned that the lining of the main wall in the region of the fire chambers soon burns out.

A sixteen foot kiln holds fifty tons of terra cotta and lasts about forty burns without general repairs. Minor repairs to the fire chambers are required in about twenty burns. It costs nearly one thousand dollars to re-line a kiln of this size. Forty burns of fifty tons make two

thousand tons, fifty cents per ton, for repairs. Last year, it cost us fifty cents for slabs and supports for every ton burned, making total kiln repairs one dollar per ton, though I think the slabs were unusually bad.

The smaller the kiln, the more burns it will stand. We had a twelve foot kiln stand about eighty burns, but it held only about one-third as much terra cotta as the large kiln. The cost of repairs is about the same, per ton.

We are burning one class of work at cone six and another at eight. This is probably higher than many of the other people are burning. A little higher heat makes a great difference in the durability of the kiln, especially in the slabs, as they span about two feet, and having considerable weight to sustain, sag when they begin to soften.

Kiln Contents.

The capacity of a kiln, sixteen feet in diameter and sixteen feet high, is thirty-two hundred cubic feet. It holds about fifty tons of terra cotta, at seventy pounds per foot, making fourteen hundred and thirty cubic feet, or forty-five per cent. of total capacity.

There are usually five movable floors made up of fire clay slabs, 24 x 24 x 3 inches. These contain two hundred and fifty cubic feet. There are about three hundred and fifty supports, 30 x 5 x 5 inches, containing one hundred and fifty cubic feet, making with the slabs, four hundred cubic feet, or 12½ per cent. of the kiln capacity. Together with the terra cotta, 45 per cent., the content is 57½ per cent., leaving 42½ per cent. of the kiln unoccupied. Slabs and supports weigh twenty-five tons, one-half as much as the terra cotta.

Size of Kilns.

There are a few minor advantages in small kilns, but they are very few. We have a five foot kiln, in which we burn replacements. It was intended to be used only in case of emergencies, but we have enough emergencies to keep it going constantly. We find we can burn fairly large

pieces in this kiln, with as little cracking and warping as we have in our larges ones, in fact, there is less settling and warping, owing to the work staying at the softening temperature a shorter time. It takes thirty-six hours to burn this kiln and one hundred and ten hours for the larger ones. The five foot kiln can be turned over in three days and the large ones require ten or eleven days. When a large one goes wrong, we wish it were a small one. This is all I can say in favor of small kilns.

The original cost of kilns is an important matter. It costs more than half as much to build a 12 foot than it does to construct a 16 foot kiln, and the former holds about one-third as much as the latter.

Fuel.

We always use bituminous coal. In a 16 foot kiln, it takes 60 per cent. of a ton of coal to one ton of terra cotta. In a 12 foot kiln, 88 per cent.; in a 10 foot, about one ton, and in a 5 foot kiln, 133 per cent. of a ton. The labor in firing is about in proportion to the coal.

While our 16 foot kilns are not large, compared with those of some of the other plants, you can see the great advantage in large kilns.

Proportion of Kilns.

As far as the setting and fixtures are concerned, there is a great saving in a wide but low kiln. It is surprising how much more terra cotta can be gotten on a floor where there are no supports, than where there are, so that where the top floor constitutes a large percentage of the total kiln floor, a saving is effected. If it were practicable to use a kiln so low that the terra cotta could be piled from the bottom to the top, all the expense of fixtures could be saved, and the cost of raising the work to the top of a high kiln, and lower it again, besides the cost of handling the slabs, would be eliminated. For every ton of terra cotta we burn, we have to handle twice, a half ton of fixtures.

It would be very difficult to get in to set a kiln of this proportion and it might be difficult to burn it evenly.

The question has been raised as to whether gas could be used and the muffle avoided. The use of gas will probably be the solution of this problem. It seems probable that an open, continuous gas kiln, could be constructed, with comparatively small and low compartments, well adapted to burn terra cotta. The combustion of the gas might be so perfect as to make the muffle and some of the fixtures unnecessary, and possibly a saving of fuel could be effected, even with gas.

Such a kiln would naturally be low and could be built in the first story of a building, the upper stories of which could be used for drying. All the heat produced in this kiln, except what little went up the stack, would go into the building.

DISCUSSION.

The Chair: Gentlemen, this interesting paper of Mr. Conkling's is open for discussion. I am sure there are some gentlemen here specially interested in the facts presented. I would like to ask Mr. Conkling about the difference in cones used inside and outside the muffle. Where was the cone placed in the muffle?

Mr. Conkling: About the center of the kiln.

Mr. Geijsbeek: I will ask how thick the lining is.

Mr. Conkling: You mean the thickness of the muffle?

Mr. Geijsbeek: Yes, sir; the muffle lining.

Mr. Conkling: At the base, nine inches; then a few courses of brick on top of that, four and a half inches; above that, about two and a quarter. The base of the muffle is a polygon, then when it gets up to this height (indicating) it is a circle.

Mr. Geijsbeek: The arch is two and a half inches, too?

Mr. Conkling: No; the dome is four and a half.

Mr. Parker: You speak about the smaller kiln lasting longer than the larger one. I would like to ask if you

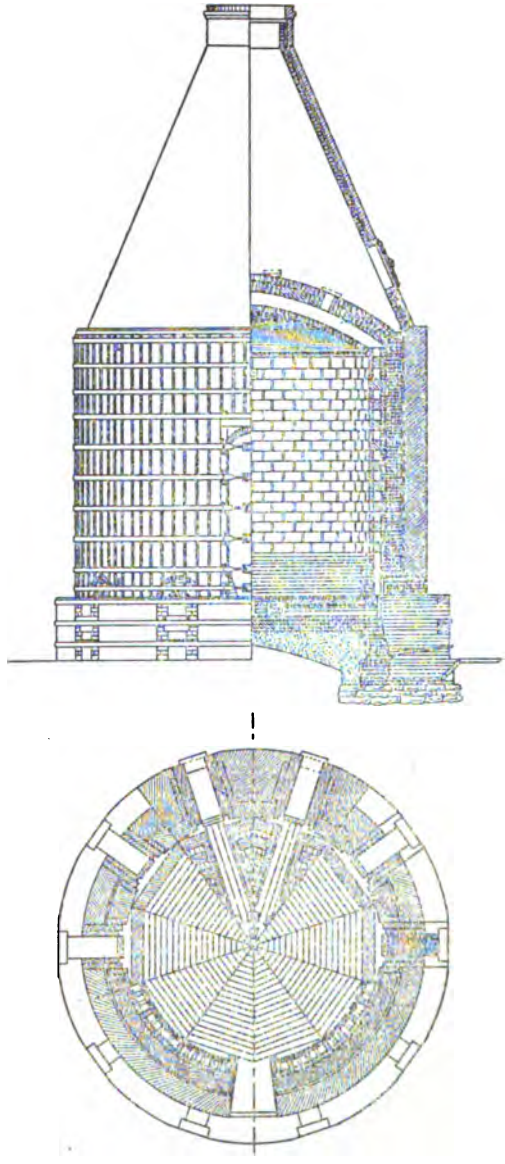


FIG. 8. Kiln of the Conkling Armstrong Terra Cotta Co.

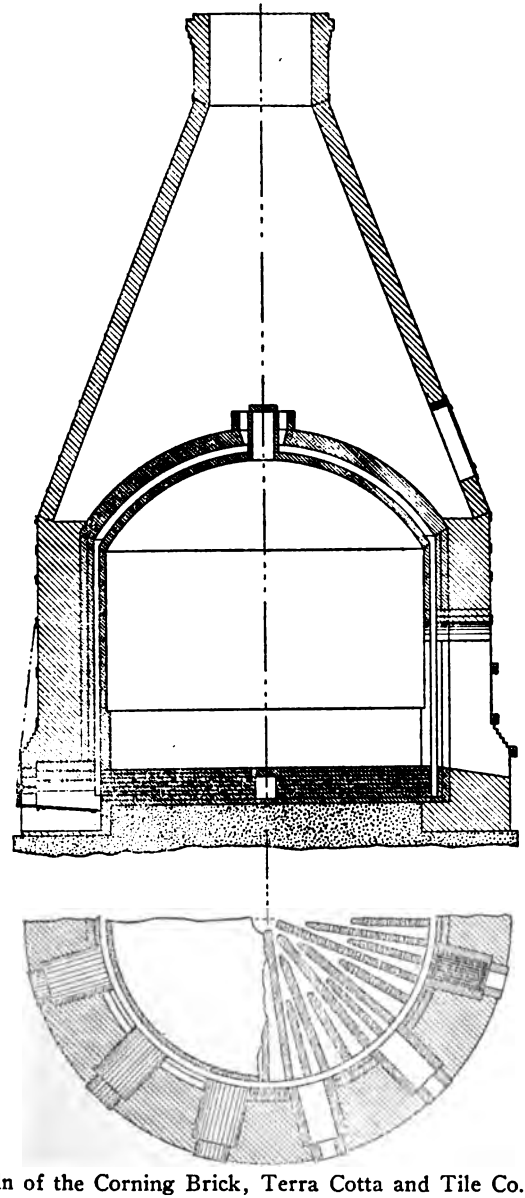
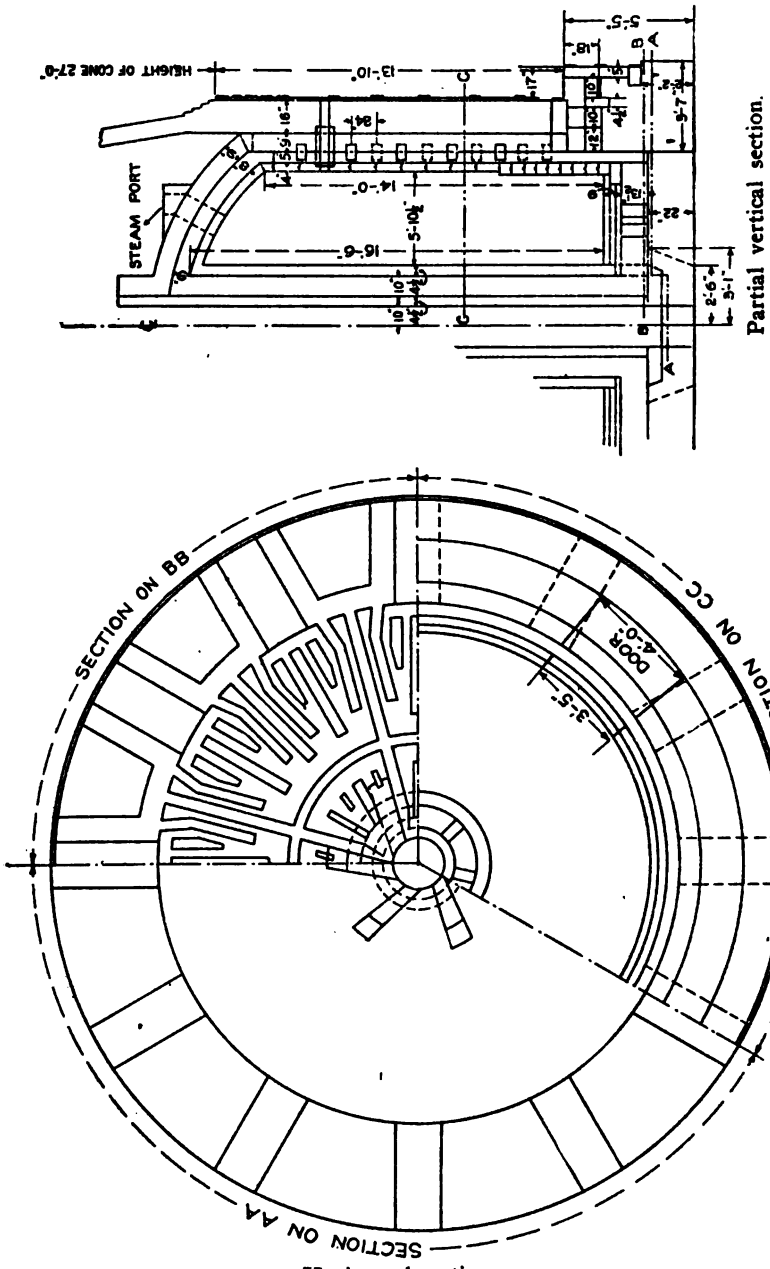


FIG. 9. Kiln of the Corning Brick, Terra Cotta and Tile Co., sent in by Mr. M. E. Gregory.



Horizontal sections.

FIG. 10. Kiln of the Perth Amboy Terra Cotta Co.

build the material to the same height in the small one as in the large?

Mr. Conkling: You mean, the height of setting the terra cotta?

Mr .Parker: Yes.

Mr. Conkling: No, sir. We set the terra cotta to the full height of the various size kilns, in tiers about 2 feet 6 inches in height.

Mr. Parker: Would not the small one have a lighter load than the large one?

Mr. Conkling: Yes, sir.

Mr. Parker: Would that account for the longer life?

Mr. Conkling: No. The terra cotta does not bear on the part of kiln that most quickly gives out. I do not think that has so much to do with it as the longer firing in the larger kiln. The brick are kept at a high heat a longer time and the gases have more chance to work on them.

Mr. Watts: Mr. Conkling said that his fire boxes burn out in quite a short time. I would like to ask whether he can tell us about the composition of the coal he is using.

Mr. Conkling: No, I cannot.

Mr. Watts: Do you know whether the coal would run high or low in fixed carbon?

Mr. Conkling: Yes; it is supposed to be high in carbon. I do not analyze it.

Mr. Watts: It seems to me from what little thought I have given to it, the proposition is something like this. We see he has gone toward the high rather than the broad kiln, which would indicate that they find the greatest relief in catching the heat as it rises. This is rather confirmed by the fact that he uses a coal rather high in fixed carbon. As we know, nearly all the porcelain manufacturers around Trenton here use up-draft kilns. I tried it, but found in order to do it I must abandon the coal I had been using, the Sunday Creek coal of Ohio, because it ran too high in volatile combustible matter and too low in fixed carbon. All the heat went out at the top of the kiln.

When I began to use the down-draft kiln, with the changed draft I got in it, I began to get more efficiency from my coal. Perhaps other terra cotta people who are using lower kilns are using coal higher in volatile combustible matter. Concerning the burning out of fire bags, I want to say that when I first went with my present company, they were having trouble with the burning out of the fire bags. They were using a coal too high in volatile matter and were burning up their bags in order to get the heat wanted in the kiln. So I think a great many of us have not in the past realized the importance of adjusting or choosing our coal for the type of kiln we are using. I find when we get a coal a little lower in fixed carbon and higher in volatile matter, we get twice the life out of our fire bricks.

Mr. Gregory: I will ask if the life might not be increased by making it lower and putting in a connecting flue at the bottom, across, connecting the bag-wall. He says he has little heat on the bottom and melts out his bag-walls.

Mr. Conkling: I do not understand.

Mr. Gregory: You said you do not get as good a burn in the bottom course of the kiln as further up, didn't you?

Mr. Conkling: I said the brick did not last as long.

Mr. Gregory: Yes, and your terra cotta does not burn so well on the bottom on account of the circulation not being so good.

Mr. Conkling: There is a slight tendency to coolness in the center bottom because we have no center stack to carry the heat through here.

Mr. Gregory: I used to have center stacks but took them out and now get better results without them. I connected the flues across to the bag wall between the arches and thereby got relief, moreover I do not have so many arches burn out as I did.

Mr. Conkling: I do not understand that yet.

Mr. Gregory: (Coming forward to chart on the wall illustrating Mr. Conkling's paper). This part of the fire

coming from the arch (indicating) goes up. That is the part that has a tendency to burn out your brick. Now, make a shaft through here (indicating on bottom of kiln) to the center, and connecting here (indicating) with the bag well, extending between the arches. Is there any question about it now?

Mr. Conkling: I understand it now.

Mr. Gregory: That will give you relief from such troubles. It makes complete circulation.

The Chair: What will pull it to the center?

Mr. Gregory: The natural draft of the kiln.

The Chair: You make it go to the center first?

Mr. Gregory: No; not all of it, just a portion. In Mr. Conkling's kiln there is nothing to pull it to the center.

The Chair: You have that under control so as to take part in the center?

Mr. Gregory: Yes, to a certain extent. By experience we have learned what size to build the flues, in order to control the heat, and thus secure an even burn.

Mr. Geijsbeek: You have two distinct flues then — one on the fire box and one underneath, and they do not connect?

Mr. Gregory: Yes, the flues connect, when they come back. When the heat comes through here (indicating) it comes back and goes through one of the flues and back to the bag wall.

The Chair: Not to the same bag?

Mr. Gregory: Yes. It goes back to the same bag wall; there is a draft there.

The Chair: If there was space enough in this muffle wall, no obstacle there, would it not go up rather than to the center? What makes it go the center?

Mr. Gregory: There is somewhat of an obstacle there, and the volume of heat drives it to the center, also the draft.

Mr. Yates: I will inquire from Mr. Gregory if he has that underflue connected with the center stack? Part

of his heat goes under the floor and up the outside. Has it ever been connected with the center flue?

Mr. Gregory: I used to have center stacks; we tore them out.

Mr. Yates: Didn't it work more uniformly?

Mr. Gregory: No, we get better results without it.

Mr. Conkling: That was the way of doing it, in the old days. We thought then the center stack was necessary to get the heat under the floor.

Mr. Booth: I will ask Mr. Gregory if one fire hole flue goes right through to a fire hole on the other side, or whether he makes a separate flue between the fire holes?

Mr. Binns: I think I can make the point clear. The system under which Mr. Conkling constructs his kilns has a series of regular flues meeting in the center, as I understand.

Mr. Conkling: Yes.

Mr. Binns: And when the draft enters those flues it is forced towards the center, where there is no outlet except through a corresponding flue from the other side, which also has a draft coming from that direction.

Mr. Conkling: There is no outlet at all, simply a space under the floors.

Mr. Binns: Mr. Gregory's point in his construction is the addition of return flues between the inlets, so that when the draft enters the center of the kiln it can return through a flue in the opposite direction. He has a double number of flues, one-half running towards the center and the other half outward from the the center.

Mr. Conkling: I understand that Mr. Gregory's heat goes through here, (indicating), and then back to the outside wall. I cannot see the advantage of the arrangement. I do not see how it would aid in getting more heat under the floor, though Mr. Gegory says it does.

Mr. Binns: I think there is no doubt of it, inasmuch as in the kiln before us we have the heat in the flues all under pressure in one direction toward the center, and nothing to draw it from there. Now, then, construct a

series of flues between these, with an outlet into the muffle wall, and it enters in one direction and then comes back in the other. Then you would get great relief from that pressure.

Mr. Yates: If I understand it, Mr. Gregory has two separate and distinct flues to the muffle, one outside to the dome of the kiln and the other under the floor connected to the center.

Mr. Gregory: No; Professor Binns has explained my idea perfectly. His explanation has covered all the points.

Mr. Ramsey: As I understand it, this flue comes to the center and a return flue goes back here, (indicating on chart), to a space between the muffle and the outside wall. What causes this draft? I cannot understand it. The heat from the fire box has a direct course up the muffle. What should take it over here to the center and back except that you may have more heat going through than you can get up here?

Mr. Gregory: I think you are right, as it is rather narrow there.

Mr. Ramsey: Have you a division wall passing up here any distance?

Mr. Gregory: The bag wall is about four inches.

The Chair: This is an interesting question, and we would like to hear from all terra cotta men on the subject, as to the real merits of the various kilns being used by them. We have men here who are using up-draft, and some who are using up- and down-draft combinations, and others using down-draft systems of various types. Mr. Gregory has explained how he would improve on the up-draft kiln to get a better bottom. I have not been able to see just how it could be done. I can see how it can be adjusted so part must go to the center.

Mr. Booth: We have a small kiln on the same plan as Mr. Conkling's, and had a dead flue like he has. We had a cold spot right in the center. We could not get the heat up on account of the dead flue. By making the fire

hole run through, it made enough circulation to keep the heat going underneath. It might be this, (indicating), would pull the heat over here, (indicating), and vice versa, knocking that deadness out of the bottom.

Mr. Conkling: There is a certain amount of opening in the center.

Mr. Booth: I know, but no live heat traveling to the center I suppose. That is why I questioned Mr. Gregory whether that did not run right across and go up opposite the fire hole. You just need a little circulation there.

The Chair: What do you mean, in an up and down-draft kiln?

Mr. Booth: No; this is a kiln like Mr. Conkling has shown, an up-draft. Where you have up- and down-draft, you have two chimneys in the center of the kiln, one inside the other. The heat goes up the muffle, over the crown, down on the chimney, underneath the floor and out through the center chimney.

The Chair: Really down-draft, with only up-draft to take the gases out?

Mr. Booth: Yes, sir. This is what I was trying to get at.

The Chair: What do you think about up- and down-draft kilns for terra cotta?

Mr. Stephani: I favor low but wide up- and down-draft kilns for terra cotta. You send the gas up the muffle, back around the muffle, under the floor, and up the center stack. In that way you get better heat distribution since the ware is entirely surrounded by the hot live gases. Your kiln is not so high and therefore you do not get so much weight of material on the floor and fixtures. This is one large advantage.

The Chair: Some kilns used in burning terra cotta are all down-draft kilns. We had some up- and down-draft, down draft where the heat goes up to the center until it strikes about here, back over the crown, down again under the bottom, and up, and the kiln in which the heat goes

over and down the stack and out by any other means. Which do you think is the better form of kiln?

Mr. Stephani: It seems to me the type which takes the gas up around the muffle, back through the muffle, and out the stack in the center, is the most economical. You use the gas once more.

Mr. Conkling: That is the point I tried to bring out. If the escaping heat in an up draft kiln is no greater than that within the muffle I cannot see what is gained by carrying it down again. It cannot add to the heat in the kiln, but if the muffle is divided into alternate flues, one for up and one for down draft, not so much heat would be taken up during its passage to top of kiln and more would be taken up, by the muffle, during its passage down. Therefore you would seem to get about the same result as is obtained in an up-draft kiln.

Mr. Watts: In using a coal lower in fixed carbon and higher in volatile matter, there is some advantage in using a kiln which takes the heat around the muffle twice and out the stack. You are getting greater heating value from coal of that kind than with coal having a higher percentage of fixed carbon. The greater advantage of the kiln of the low, broad type is that you do not stack so great a weight on the slabs in the kiln, as compared with the narrow, high kiln.

Mr. Orton: Mr. Conkling speaks of having trouble from the burning out of the fire boxes; have you tried silica brick?

Mr. Conkling: I tried silica brick in other parts, back of the muffle, in here (indicating), but while they did not burn out, I found they crumbled away and fell out.

Mr. Gates: I think the sudden heating and cooling would ruin silica brick in that position; but if the heat was continuous, then they would stand.

Mr. Binns: I will ask Mr. Conkling if he has not provided too little protection from radiation? My impression is that the loss is very large. If you can save the radiation you will accomplish a great saving of fuel. That,

I think, is one great advantage of the down-draft kiln, in checking radiation to a great extent.

Mr. Conkling: It is not really necessary, to my mind, to have all the muffle we do have. At one time I extended a very thin muffle up about one-third the way. My idea was that having a thinner muffle, there was less surface, and still we could get the heat in the kiln. There was a sort of box built in front of each fire chamber, and then we had a center stack. The heat went up there, (indicating), and the draft out this way, (indicating). I found I could get it up to a very light red burn. I had no means at that time of testing the temperature, but I am quite sure if that were extended up half way we could burn off our kilns in as little time as now. I think it is not necessary to have all that wall space to take up the heat generated in the fire box. The air becomes heated next the muffle, and being lighter than the other air in the kiln ascends; and the cooler air must be drawn out from the center at the bottom. A constant circulation is in this way kept up and that is why we get such even burns without a center stack.

Mr. Stover: I would like to ask some gentleman who has had experience with the low, broad kiln, about the fuel tonnage to the tonnage of production. In the high kiln there must be put in a greater percentage of fixtures to take up the heat units; and the lower kiln would give a greater tonnage of ware burned for the space occupied.

Mr. Geijsbeek: I don't think the amount of fixtures in a high kiln cuts much of a figure. If you have a broad kiln, you have more fixtures over the floor. I do not think that would make much difference.

Mr. Conkling: I think Mr. Stover is right. In the low, broad kiln there is a smaller percentage of slabs and supports; and if I were building a plant now I would build low, broad kilns. Ours were built about eleven years ago, and we have learned a few things since. I might say that the second floor of our building comes up about to this point, (indicating), and all our ware is taken in there, so that we do not have much lift. Then everything goes

down to the first story, and out. So, as to the matter of convenience in loading the kilns, I think it is fairly well built. But if the plant were one story high, I would say have low kilns, by all means.

Mr. Stephani: In regard to Mr. Stover's question, it seems to me the economy in the low, broad kiln, over the high kiln, is that in the low kiln you are not so hard on the fixtures as in the high, narrow kiln; the posts do not bend and the slabs don't crack so much. You haven't the weight on them. In using a gas coal, highly volatile, better and more uniform heat distribution is obtained and the boxes are not burnt out as must happen when one has to get the required heat in a kiln of Mr. Conkling's type. This saving in fuel and kiln repairs is very great.

The Chair: Mr. Conkling is using a kiln of small diameter and high. We would like to hear from some one who is using the low broad kiln.

Mr. Boleschweiler: I think I can answer all these questions by referring to two kilns I have built. One has been used four years. I am going to do away with the other kind as soon as they are in condition to need repairs. The kiln is thirty feet in diameter, inside, and high enough for a man to stand upright, and holds 120 tons of terra cotta. The entrance to the kiln is on a level with the ground, making it very easy to set. My idea was derived from what we call the old Swiss kiln, which is nothing more than a tunnel. I have always been taught that the lower the kiln the better it burns. I only have one floor of slabs about that high, (indicating), and above and below that I pile the terra cotta. The door is wide enough to take in any piece of terra cotta we make. We make some large pieces, put them on trucks, wheel them in and set on the floor. The fire burns through the fire hole here, (indicating), comes up, back again, and underneath the floor. The waste gases are conducted over to the factory, underneath the drying floor, so that we utilize every ton of coal which we burn in those kilns. The kilns

are very good and successful and I wish I had them all that way.

Mr. Booth: How much coal do you use per ton of terra cotta.

Mr. Boleschweiler: Seventy tons of bituminous coal for 120 tons of terra cotta. I have not calculated the cubic feet of space taken by slabs and blocks, and hence could not give those figures.

Mr. Orton: What sort of draft have you? How do you cause your draft, by chimney or fan?

Mr. Boleschweiler: Natural draft. There is a flue, 180 or 200 feet long, leading under the factory, and a stack at each end of the building, not a very high one either.

The Chair: How high is the stack?

Mr. Boleschweiler: I would say, probably forty feet from the ground.

Mr. Burt: Approximately, what heat have you in the kiln?

Mr. Boleschweiler: Cone eight. We burn glazed terra cotta, semi-glazes, everything in this line.

Mr. Parmelee: You say the heat goes up, and comes down, inside or outside?

Mr. Boleschweiler: The heat goes up here, down here, and is taken from over there to the factory, (illustrating on chart).

Mr. Orton: Will you furnish a diagram of the course the heat travels, so that it may be incorporated in the records?

Mr. Boleschweiler: Yes, sir; I will.

The Chair: Mr. Stephani has the same kiln, except it is higher.

Mr. Stephani: It is not so large in diameter. I will ask Mr. Boleschweiler if he has a central stack in case he does not care to take the gases to the factory?

Mr. Boleschweiler: I did use one, but took it out. It took up too much space and when we let the heat in through the factory it was not needed. Instead of letting the good heat go out into the air and heat up the beautiful

surroundings of the factory, we thought it would be better to take it through the factory and dry the stuff with it.

Mr. Orton: Mr. Conkling, did I understand you correctly to say that there was little difference in the amount of heat consumed between a kiln in which the gases travel directly through the ware and a muffle kiln?

Mr. Conkling: Yes, sir.

Mr. Orton: There is a popular estimate among brick men that it takes about one ton of coal to a thousand brick for all purposes, boilers, dryers, and kilns. Figuring a thousand brick as weighing nearly nine thousand pounds, it makes something like one pound of coal to four and one-half pounds of clayware. What figure do you give for your ware?

Mr. Conkling: I figure about 60 per cent. of a ton of coal to one ton of terra cotta in a sixteen foot kiln. The larger the kiln, the cheaper we can burn. I also stated in my paper that if a kiln were closely packed, more heat would be taken up by the objects being burned, in the early stages of firing, than would be taken up by a muffle surrounding the same bulk of material in the same time, at the same temperature and at the same stage of firing. I think there is a certain gain there, of course. But you cannot pack terra cotta in a kiln in the way you can brick. In a kiln 16 feet in diameter, we will pack 45 per cent. of the space with terra cotta, and 12½ per cent. will be occupied by the necessary fixtures, leaving 42½ per cent. of the kiln space unoccupied. There is not so much there to take up the heat. From our experience with open kilns of the same size, burning fire-flashed work, I think there is not very much saving.

Mr. Orton: The average paving brick kiln is twenty-eight or thirty feet, perhaps from twenty-four to thirty feet, in diameter. Your estimate then, sixty per cent., would be 1,200 pounds of coal for 2,000 pounds of ware, or one pound of fuel to one and sixty-six hundredths pounds of clay. It seems to me the difference is very great.

Mr. Conkling: But see how much more of weight of

brick you could get in the kiln. Our ware is hollow. That is where the difference comes. Our terra cotta only weighs about seventy pounds per cubic foot, and you get about 125 pounds per cubic foot in brick, and as stated above, only 45 per cent .of space in kiln is occupied by terra cotta. Besides, the muffle in our kilns takes up space that would be occupied by brick if they were being burned in this kiln open, without the muffle.

Mr. Stover: What we are trying to bring out is tonnage of fuel vs. tonnage of material.

Mr. Conkling: The gentleman who preceded me said he burned to cone one, while we burn to cone eight. There is a difference there.

Mr. Yates: I would be pleased to listen to the gentleman who burns a thousand paving blocks with one ton of coal.

Mr. Fickes: That is just what it requires in our plant, in four years' experience of which we have kept account.

ADDITIONS OF LIME TO AN EARTHENWARE BODY.

BY

H. E. ASHLEY, East Liverpool, Ohio.

The presence of calcium carbonate in an earthenware body is generally considered as the source of various evils, more especially sudden vitrification and warping. The presence of calcium fluoride is supposed to give even worse effects, especially a swelling due to the formation of bubbles of gas. Having the idea that these bad effects might be due to the excessive amounts rather than to the nature of the additions, I prepared a series of tests with only small additions to an earthenware body. The batches were as follows:

Body.	B H	C	E	D	F	K	M	L	N
Tenn. Ball Clay No. 3	22	22	22	22	22	22	22	22	22
English China Clay..	36	36	36	36	36	36	36	36	36
Potters' flint	34	34	34	34	34	34	34	34	34
Feldspar	8	8	8	8	8	8	8	8	8
Fluorspar	. ...	0.1	. ...	0.3	.....	1.0	.....	3.0	.....
Whiting	.....	....	0.13	. ...	0.4	...	1.0	.....	3.0

The batches were wet ground in a ball mill for one hour, dried in plaster paris moulds still stiff enough to wet press into tile. The tile were about 11.25 cm. square by 0.9 cm. thick.

These were fired to cone 3 or 4 in a small brick updraft muffle kiln at the Ohio State University. The muffle leaked somewhat. The fuel was soft coal and coke. The burns lasted about 14 hours; of which the last four were at the maximum temperature.

The first burn comprised bodies BH, C, E, D, F; the second burn, bodies BH, K, M, L, N.

The total shrinkage from mould dimensions is given in the following table of percentages:

Body.	B H	C	E	D	F	K	M	L	N
Per cent. Fluorspar..	....	0 1	.....	0.3	.....	1.0	.....	3.0	.....
Per cent. Whiting....	....	....	0.13	....	0.4	.....	1.0	.....	3.0
Per cent. Shrinkage..	10.5	11.1	11.1	11.1	11.3	10.8	10.8	11.4	12.7

These results are also shown graphically in the accompanying diagram, figure 11.

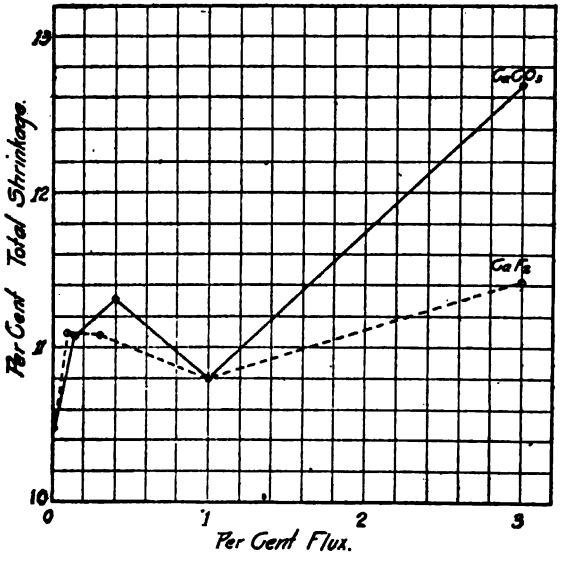


FIG. 11. Relation between per cent flux and shrinkage.

The first small addition of flux has produced a marked increase in shrinkage. Notwithstanding the irregularity at one per cent. flux the general effect of further additions, up to 3 per cent., is still further, but more slowly, to increase the shrinkage. The whiting is more active than the fluorspar in producing this increase.

The amount of water absorbed is to be expected to fall off as the shrinkage increases with increased fluxes. The results are:

Body.	B H	C	E	D	F	K	M	L	N
Per cent. Fluorspar..	.....	0.1	.....	0.3	.....	1.0	.....	3.0	.....
Per cent. Whiting....	.....	.....	0.13	.....	0.4	.....	1.0	.....	3.0
Per cent. Absorption.	10.6	10.2	9.0	9.4	8.5	8.2	7.7	6.8	5.4

These results are shown graphically in figure 12.

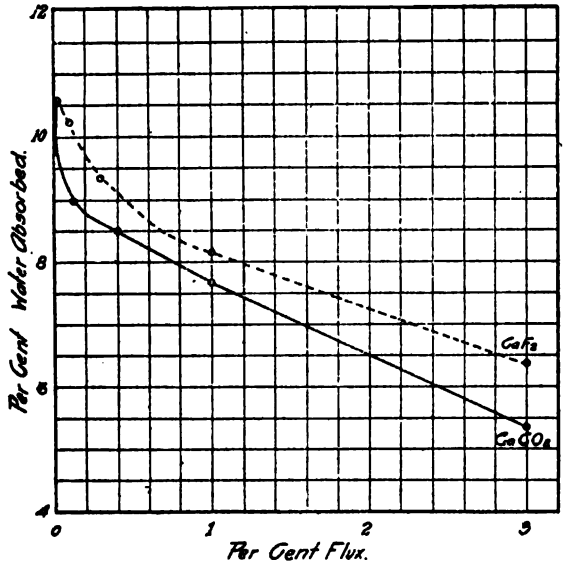


FIG. 12. Curve showing relation between per cent flux and absorption.

Every increase of flux has decreased the amount of water absorbed. The whiting is more active than the fluorspar, in equal amounts by weight.

To test the translucency, one of the tiles of each composition had a wedge shaped groove whittled in it while

still green. After firing the tile was held close to an incandescent or electric light, and the translucent region outlined with a lead pencil. The thickness at the pencil mark was then calipered. The results are as follows:

Body.	B H	C	E	D	F	K	M	L	N
Per cent. Fluorspar..	.....	0.1	....	0.3	.....	1.0	.....	3.0	.....
Per cent. Whiting...	.....	.....	0 13	.....	0.4	.....	1.0	.....	3.0
Thickness passing ligh (m. m.)	1.65	1.9	1.9	1.8	2.3	2.1	1.7	2.4	2.0

The results are shown graphically in figure 13.

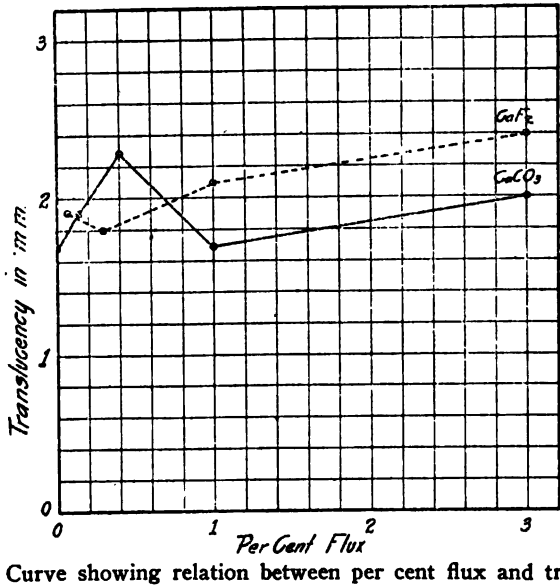


FIG. 13. Curve showing relation between per cent flux and translucency.

The irregularities with the small percentages are probably due to irresgularities of temperature distribution in the kiln. The fluorspar, though less active in promoting shrinkage and tightness, appears the more effective in pro-

ducing translucency. As but a single wedge was made in each case, these results must not be given much weight. The limiting thickness passing light appeared to be the same whether the light were from a 16 candlepower electric light or from a Welsbach gas burner; also whether the test was made in the bisque or on the glazed trial.

All of the trials had sufficient hardness to be marked with a black streak by the point of a knife blade.

The strength of body was measured by a rattler test. Each tile had been scratched before firing along lines dividing it into four quarters. After firing it was broken along these lines, marked in common ink with its letter, but into a small ball mill with 7.5 lbs. small porcelain balls and 22.7 lbs. larger flint pebbles and sufficient water to cover. It was ground at about 50 revolutions per minute for one hour, taken out, washed, dried, weighed, put in as before, ground a second hour, taken out again, washed, dried and again weighed. The ink marks were plainly visible throughout the test.

The results are:

Body.	B H	C	E	D	F	K	M	L	N
Per cent. Fluorspar..	.....	0.1	.....	0.3	.....	1.0	.....	3.0	.....
Per cent. Whiting....	.....	.....	0.13	.....	0.4	.....	1.0	.....	3.0
Per cent. Loss, first hour	2.81	2.34	2.39	2.74	2.22	1 7	1.7	1.6	1.3
Per cent. Loss, second hour	2.13	1.64	1.93	2.32	1.96	1.0	1 5	0.9	1.3
Per cent. Total loss..	4.94	3.98	4.32	5.06	4.18	2.7	3..	2.5	2.5

These results are shown graphically in figure 14.

Excluding the irregular result with 0.3 per cent. fluorspar, additions up to 1.0 per cent. fluorspar or whiting produce a marked improvement in strength. Further additions up to 3 per cent. effect an additional slight improvement. The fluorspar produces the stronger body when used in equal amounts.

It is believed that the irregularities shown in my results are largely due to the difficulty in securing uniform distribution of heat in a small muffle, and that these difficulties were better overcome with the trials containing 1 and 3 per cent. flux, than with those containing less than 1 per cent.

As my tests were burnt to but one temperature, the investigation throws no light on the evil of sudden vitrifi-

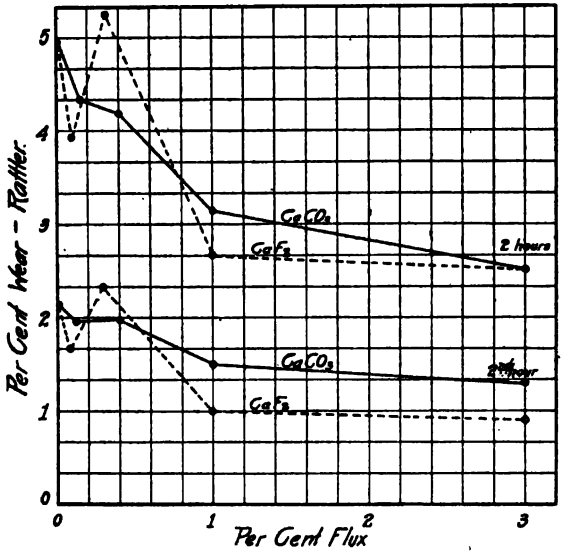


FIG. 14. Curve showing relation between per cent flux and loss in abrasion test.

cation. Nor does it throw any on the question of warping. In the recent investigation of Reinhold Rieke* on mixtures of magnesite and Zettlitz kaolin, no swelling was observed until 17 per cent. of the mixture was magnesite and the temperature had reached cone 14. I believe that similarly, a small enough addition of calcium carbonate will not produce swelling. The limit is undetermined. But as to the

* Sprechsaal (1905) [47] 1910.

use of fluorspar, most emphatically, no signs of swelling were detected in this work.

Summary.

Additions of lime to an earthenware body, as whiting or as fluorspar, in amounts not exceeding three per cent. increase the shrinkage, very markedly, decrease the porosity, somewhat heighten the translucency, and very decidedly raise the strength.

Whiting is more effective than fluorspar, in equal amounts, in increasing shrinkage and decreasing porosity.

Fluorspar, on the other hand, surpasses whiting in promoting translucency and in raising the strength. Whiting or fluorspar in amounts not exceeding 3 per cent. at cone 3-4 do not produce swelling.

Sudden vitrification and warping were not studied.

DISCUSSION.

Mr. Parmelee: I will ask whether there was any sign of any action of fluoride in this case, any bubbling?

Mr. Ashley: No sign of any bubbling. Professor Orton showed me an account of a test where some fluoride was used and there was very bad bubbling, but I got none whatever.

Mr. Binns: This throws a little light upon a problem that has often vexed us, viz., the relative action of Cornwall stone and feldspar. We are unfortunate in this connection in not having, or not having yet been shown a deposit of any rock similar to the English Cornwall stone. I hope some day it may be found. There is no doubt in my mind that the difference in action between Cornwall stone and feldspar is largely due to the fact that the Cornwall stone contains quite a percentage of fluorine. The light thrown on this subject by this paper shows us one reason why the potters in England have been able to do some things we have not been able to accomplish.

THE POROSITY OF AMERICAN ROOFING TILE.

BY

H. A. WHEELER, St. Louis, Mo.

Roofing tile in America is subjected to more severe action from frost than any other clay product, with the possible exception of paving and sidewalk brick. It receives the full effect of every rain and the more severe action from the slow melting of accumulated snows. The sudden freeze that frequently follows our winter rains finds the tile soaked with water and, therefore, in a most vulnerable condition for frost disintegration. Building bricks are usually so well protected by cornices, overhanging eaves and drip courses of stone or terra cotta that they seldom become water soaked, even in a driving rain. Their greater thickness, about 4¼ inches as compared to the ½ inch tile, would also greatly reduce the effect of freezing strains, even if water-soaked, owing to its poor heat conductivity which retards the freezing so as to give ample time for the expulsion of the surplus water into the interior of the wall.

It is, therefore, an interesting study to see how successfully the roofing tile on the American market has met the severe conditions incident to its use and what amount of water it usually absorbs. The product of the new factories is not considered in this article, from the lack of time to test their tile on the roof. All the examples subsequently quoted have been ten to thirty years on the market and therefore have been tested to at least this extent by actual use.

As the roofiing tile industry is comparatively new in the United States, the manufacturers naturally followed the precedent of the European factories in making a rather soft, quite porous tile. For, the softer a tile is burnt, the lower is the cost of manufacture, owing to the very greatly increased loss from warping and checking that occurs in

hard burning. As tile has had a hard fight in entering the American market, where it has to contend with the much cheaper slate and still cheaper shingles for roofing, any factor that would cheapen the cost is of importance. While the quality of the tile has improved and the cost has been reduced in recent years, it is still regarded as such an expensive roof that it is seen on only the higher grade of buildings.

The soft porous tile also has an important advantage in being a better non-conductor of heat than a hard tile, which materially adds to the comfort of the roof. In fact in Mexico, where tile are almost exclusively used for roofing, the clay is scarcely baked hard enough to resist rain disintegration, and they are so very porous that they leak to some extent until dirt chokes up the pores.

American tile-makers have found it necessary in most cases to burn their tile harder than is customary in Europe, on account of our more severe winters, yet some of our tile are quite porous and are only given a light burn. The following table shows that the American tile that have had over ten years' successful use range from 1 to 21% absorption, after 24 hours' continuous immersion in water. The broad statement that the less porous a brick or tile the less the risk of frost distintegration is still upheld as a *general* proposition by the table, but the risk of grave error in *sweepingly* applying this rule is also clearly shown by the same table. Three different tiles that absorb 12% or more have thus far proved quite as satisfactory as six other tile that absorb 6% or less after 24 hours' soaking. All the tiles cited have been used along the 40th or Indianapolis parallel, in which the violent fluctuations of winter weather are most severe, and, therefore, the most trying on roofing tile.

The great variation in intermolecular strength of burned clay that enables one very porous body to successfully resist frost while another much less porous one is completely disintegrated came under the writer's notice on an Illinois brick yard. One brick that was hard-burned and having an absorption of only 5 to 7% would completely

disintegrate in one winter, while a salmon brick alongside of it, but made from a different clay, successfully withstood years of freezing although it absorbed 22%. This marked variation in the ability to resist frost has been attributed to the pores either being *closed* tubes or *open continuous* tubes. In the latter case the 10% increase in volume that water experiences in passing into the solid form could relieve itself by expelling the excess from the protected or unfrozen side, whereas the *closed* tube, having no such outlet for the escape of the excess of water, would rupture and disintegrate the brick or tile if frozen when water-soaked. This explanation is questioned by the writer, for the shale employed in sample, *H*, when worked in a dry-pan and pug mill made a brick that would completely disintegrate *in one winter* unless burnt very hard, or with less than 5% absorption, whereas the very soft burnt tiles, with 14% absorption, have successfully resisted frost for over ten years on the roof and in very severe laboratory tests. But in making the tile, the shale is ground *finer* in the dry pan and worked *very thoroughly* in a *wet* pan in a softer condition and therefore its *intermolecular strength is very greatly increased.* Hence in the latter case the poral tubes have sufficient strength to resist the severe freezing strains and compel the excess volume in freezing to extrude itself, whereas in the brick the tubes are ruptured from sheer lack of strength.

Again tiles *A* and *B* which are both made from shale, had to be *hard burnt* before they could resist frost, which shows they had insufficient intermolecular strength until it was increased by *harder burning,* since up to a certain limit the harder the clay is burnt the greater is its strength. Why one clay should have a much higher intermolecular strength than another is part of its individuality, and can be no further explained than why they differ in plasticity.

An inspection of the table shows that the soft or more porous tile have such large pores that the poral tubes are almost completely filled within fifteen minutes after immersion. This is noteworthy in showing that soft tile can

become water soaked from even a short rain, so that if lacking in strength to withstand freezing strains, its life is liable to be very short in our northern winters.

This discussion of frost resistance is based solely on the normal conditions under which brick or tile are used, in that they *rest on one protected surface.* This is the *underside* of roofing tile or the *inside* of the wall or the *ground* in the case of brick. This condition of one *protected* side is *absolutely necessary* for any porous material, whether tile, brick, terra cotta or stone, to prevent its disintegration by frost. For if a water soaked, porous body is hung by a string and then frozen, as the outer pores are all promptly closed by ice, there is no exit for the excess of volume developed by the freezing, and if the cold is so increased as to congeal all the water, rupture of the body will take place which will be the more violent the more porous or the larger the volume of water that passes into ice. In actual usage there is always one or more protected sides at a temperature of 32 degrees or higher when freezing begins, and as the cold travels from without into the body of the porous tile, brick or stone, congealing the water as it advances, the excess volume flows out through the protected side where it will be found accumulated as a sheet of ice, if the cold finally penetrates through the entire mass.

Absorption of American Roofing Tile.

Tile	Per cent. of Water Absorbed in					Remarks
	¼ Hr.	1 Hr.	10 Hrs.	24 Hrs.	48 Hrs.	
A ...	0.1 to 0.2	0.2 to 0.7	0.4 to 1.4	0.4 to 1.8	0.8 to 2.7	Very dark red, vitrified.
B ..	.....	0.1 to 3.2	0.1 to 3.6	0.3 to 3.7	0.3 to 3.8	Very dark red, vitrified.
B-1 .	.....	0.3 to 1.5	0.6 to 2.4	0.8 to 2.6	1.0 to 2.8	Dark gray, hard burnt.
C ...	12.0	12.0 to 12.2	12.5 to 12.6	12.7 to 12.8	13.2 to 13.4	Light red, burnt medium hard.
D ...	0.7	0.9	2.2	2.8	3.1	Dark red, hard burnt and glazed.
E ...	5.4	5.6	5.7	5.9	6.0	Medium red, well burnt.
E-1 .	.....	5.3 to 5.8	5.5 to 6.3	5.5 to 6.3	5.6 to 6.4	Brown, hard burnt.
F ...	20.0	20.1	20.8	21.5	21.5	Light red, soft burnt.
G .	4.0	4.7	5.5	6.0	6.4	Very dark red, hard burnt.
H ..	0.1	0.3	0.3	0.3	0.3	Very dark red, vitrified.
H-1 .	1.4 to 2.4	2.1 to 3.8	2.2 to 4.8	2.3 to 4.8	2.4 to 4.9	Dark red, hard burnt.
H-2 .	.....	6.7	6.8	7.1	7.2	Medium red.
H-3.	6.5 to 6.8	6.5 to 6.8	6.9 to 7.1	6.9 to 7.1	7.1 to 7.4	Light red, soft burnt.
H-4 .	11.9 to 14.0	11.9 to 14.0	12.2 to 14.4	12.2 to 14.3	12.5 to 14.4	Very light red, very soft burnt.
H-5 .	8.4 to 8.7	8.4 to 8 7	8.5 to 8.8	8.5 to 8.8	8.6 to 8.9	Buff, medium burnt.

A COMPARISON OF THE VARIOUS MAKES OF SEGER CONES ON THE MARKET.

BY

H. E. ASHLEY, *East Liverpool, Ohio.*

The occasion for this comparison was the peculiar behavior of some German cones that we were using in a trial kiln. The order in which they came down was 6, 4, 5.

Eventually cones of the following origins were compared:

German, marked with a sceptre, from the laboratory of the Thonindustrie Zeitung.

German, unmarked, otherwise identical in outward appearance and manner of packing with the preceding.

Edward Orton, Jr., Columbus, Ohio.

J. & E. Mayer, Beaver Falls, Pa.

David C. Thomas, Wellsville, Ohio.

Holdcroft & Co.'s Patent Thermoscopes were also compared with the cones. They consist of straight, dry-pressed bars, placed horizontally with support at either end. Under the influence of heat they sag in the middle.

The method of investigation was to make up slabs carrying the different makes of cones, and place them in various parts of ware kilns in regular burns. Their condition was observed when the kilns were withdrawn.

The order in which the cones came down or the bars sagged down, is shown in the diagram, where each make is given a vertical column, and cones melting together are on the same horizontal line. The Columbus cones are spaced equidistant on this diagram, for convenience only as I had a full set of these. Really 3 and 4 of the lot tested were so close together that occasionally 4 would come slightly in advance. This error was corrected in the next lot received. The standardization burns may have been shorter than those to which I subjected them, for Or-

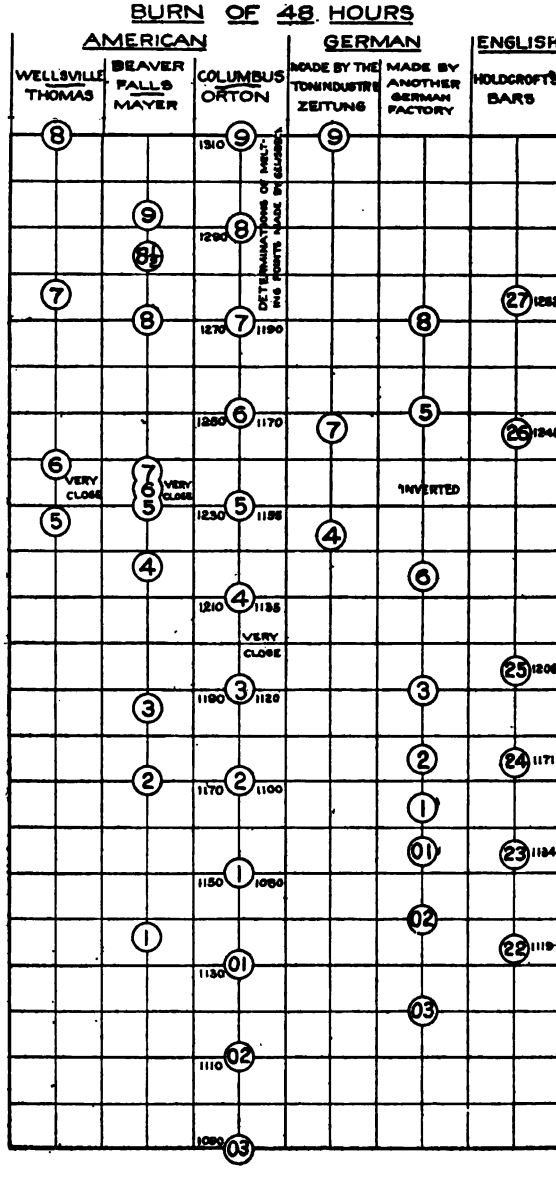


FIG. 15. Diagram showing relative melting points of different makes of Seger cones.

ton (Trans. VI., 105) says, "It does not follow that the order in which they fall on a short fire will be repeated in a long fire."

The temperature at which they are supposed to fall as given out by the Thonindustrie Zeitung is shown in the column of figures to the left of the Orton cones, while the temperatures at which they were found to fall by Geijsbeek in an article on this subject, (Trans. A. C. S., vol. VI, p. 96), are given in a corresponding column on the right. The temperatures at which Holdcroft's bars are said to fall is also given in the appropriate column.

It will be noticed that with the Wellsville and Beaver Falls cones, 5 and 6 came down very close together, and with the plain German cones in a badly inverted order. Seger, in his original paper (Collected Works I., 246), says: "I want to observe that the temperature difference, which mark the melting points, are not constant . . . . . 5, 6 and 7 do not vary much in regard to melting point . . . . . but I did not desire to do away with the cones 5, 6 and 7, because their numbers correspond to the acidity. Orton (Trans. VI., 104), says: "I find it almost impossible to make cones four, five, six, seven, and eight, so that one will not sometimes overtake the other.

The maker of the Holdcroft bars has struck boldly at this difficulty. Bar 25 is equivalent to cone 3, bar 27 to cone 7 or 8. Consequently bar 26 takes the place of cones 4, 5, 6, and possibly 7. However, I do not regard the Holdcroft bars as being nearly so sharp and accurate in their indications as the cones.

With regard to the shape of cones, the American run out to a sharp apex, while the German are cut off some distance down from the apex. The fall of the German cones, perhaps from this cause, is quicker, less gradual, than that of the American cones. The surfaces of the German cones are truer than with the American makes. Seger (Collected Works I., 248), says: "They are . . . . . made hard by an addition of mucilage. If they are rubbed somewhat on a moistened fire clay tile, they will firmly

unite with the latter in drying." A finger print on the base of the American cone prevents this, and the common practice is to stick the bases of the cones into lumps of clay. These should be promptly dried. If this precaution is neglected, the enamel kiln cones 011 to 022 (J. & E. Mayer) are liable to fall from boiling at the base long before the proper temperatures are reached. The cones are more liable to break while damp.

I have good and sufficient evidence that each of these American makes of cones has given reliable service for long periods in burning kilns, but, as our head fireman puts it, "If you mix different men's cones, you don't know what's going to happen."

DISCUSSION.

Mr. Coulter: The only matter I might speak of in this connection is the boiling of cones when heated up too soon. I had not noticed it with the cone numbers mentioned, because we were not making these. But on high numbers I account for it by the iron being reduced by the dextrine in them. The iron in the base of the cone is hindered from oxidizing by being surrounded by the clay in a most condition. But in the others I do not see why they should boil, for the flux is a lead soldium silicate, and they contain no iron.

The cones four, five, six, and seven, as we are making them now, are probably soften than when these experiments were made some time ago. Our cone three has been made softer so that the interval is wider now than when first made, and it is more satisfactory for that reason. Still, it may be closer than the intervals of the cones higher and lower.

Mr. Orton: I notice that in the cones credited to my factory, on the diagram, our number four, is softer than anybody else's number four. I will ask you, Mr. Ashley, what you intended to represent?

Mr. Ashley: It is softer than the Thonindustrie cone and softer than Mayer's. I did not test Thomas' cone.

Mr. Orton: There may be good reason for that. We had enormous difficulty in getting cone four soft enough. In making it according to the regular formula we have been in trouble with cone four half the time. So we finally hit upon replacing a portion of the lime with a very small amount of zinc oxide. We found we could run the melting point down very quickly and the question was how little to use. Finally we reduced it to something like .025 equivalent and we reduced our melting point as close to cone three as desired.

But after all, it is the old story — not enough room between three and eight to put in so many cones without running them into each other. If fired consistently, under the same conditions, a man can make a series that will stand; not otherwise.

Mr. Ramsey: Do you find that the more zinc oxide you use up to a certain amount, the softer the cone?

Mr. Orton: Yes. Of course, we did not make an investigation to see how far we could go. We started out with about .03 equivalent, and are using now about .028 equivalent. We did add more than that in the first few trials and found that it cut the melting point below cone two; so we kept reducing the amount until we reached this figure.

Mr. Ramsey: I wanted to know how much you can use and not spoil the cone.

Mr. Orton: A small quantity additional would probably produce no undesirable chemical effect other than to reduce the melting point. If it was desired to use zinc oxide in reducing the melting point of a bristol glaze, no doubt you could do so, up to about .20 or .30 equivalents. Above that, the zinc begins to act as a refractory material.

Mr. Binns: There are several points in this discussion which may be worth bringing out. The first is the one which has just been raised. It would seem as though if it is possible to reduce the melting point of cone four by the introduction of zinc oxide, it might be possible to eliminate almost entirely the iron oxide and avoid a great deal of the

reduction which we sometimes get, though I have never found it a very serious bar.

One word in regard to the point of boiling at the base of the cone. It has never occurred, in my experience, in connection with a moist clay base, and I have never found it in any cone that did not contain boric acid, and it has always occurred in conjunction with hardening of the corners. I always attributed it to the influence of the boric acid slowly filtering through the body of the cone and volatilizing.

I have been informed by the makers of the English bars that they are burned to within four bars of the point of fusion; that is, number 25 is burned to number 21 temperature before it is packed for shipment. It occurs to me it would be a good deal of an advantage to do away with the mucilage with which the cones are made. We should get rid, if possible, of the breaking at the base which happens from a temporary softening of the cone by insertion in moist clay.

There is one point upon which I wish we had the courage to make a departure, that is in the number of cones. I do not know whether we are strong enough to do it. The Germans have led the way and in order to make our literature comparable with that in other tongues, we must keep this cumbersome numeration. The English bars are more reasonably arranged, though I quite agree with the criticism that they are far less sensitive than cones. The English potters adhere to the use of them, and their use is increasing, but the cones are more sensitive. The English bar begins to sag and sags out of all recognition before anything can be done in firing, while cones allow more careful work. If you want to find fault with cones, you can undoubtedly do so. There is nothing under the sun you cannot find fault with; and many manufacturers opposed to the use of them would point to such a table and say, "That illustrates how unreliable they are." On the other hand, there is not the slightest difficulty in arranging to burn with them by the use of a little common sense,

and some consideration for the errors which, after all, are human, and we are enabled to get along with these better than with anything else, even though they are imperfect.

Mr. Watts: I want to ask if it is not possible that one fault with the English system is the fact that they are partially burnt: if that does not cause, to a certain extent, the tendency to fuse down suddenly, instead of melting slowly as the cones do?

Mr. Ashley: I have taken the English bar and stood it on end in clay, the same as with cones, and found it acted more sharply than when used in the way prescribed for them.

Mr. Orton: One practical difficulty in the matter indicated by Mr. Watts is this, viz.: You must calcine a batch of bars each time at exactly the same temperature and occupy exactly the same time in reaching that temperature, if you wish to reach the same pyrometric effect. I had some conversation with Mr. Jackson who is the technical man behind the Holdcroft Thermoscope, when he was here and I showed him through my factory and we compared notes. I asked him about this point of burning bars in advance and he admitted it was a great bore and that he was sorry they had started to do it; but having started it, they did not see any good way to stop; his English brothers would not let him.

Having made a batch of bars and satisfied himself that the melting point was correct, he would then have to go to work and run a special kiln to the exact temperature to get it calcined, and it was not always convenient to do it. The result was that he was running around the neighborhood, asking the loan of space in this and that man's kiln, and that made irregularities which he could not control, because of differences in the duration of the burn. To do this preliminary calcination properly, involves the erection of a suitable kiln, to be fired under conditions as closely uniform as possible, to get satisfactory results. That would add considerable to the cost of the cones. Whether there is any advantage in it is

doubtful and whether there would be advantage enough to justify it, is still more doubtful.

Mr. Binns: When Mr. Jackson was talking with me he made a strong plea for the burning of the bar. He seems to have taken quite a different line while talking with Professor Orton. We will have to balance one statement with the other.

Mr. Hensel: In some experimental work, we were directed to put the cones directly into the hot fire with an iron spatula. We found we could not use the raw cones that way, and would have to calcine our cones to get any reading at all. They were calcined to about cone 05, I suppose. I do not know how much we hurt the accuracy of our results by that.

Mr. Orton: Not much, at so high a temperature as that at which you worked.

Mr. Ogden: I think the practice of setting the cones in clay has two objections: One, is the danger of putting them into the kiln while the clay is still moist. Another, if a man is careless he may set some cones deeper in the clay than others, giving more support to those set deep than those more shallow. I have seen that overcome in a tile factory, in this manner. They made up a number of cheap tiles and allowed them to dry perfectly. The cone was rubbed with a piece of coarse sandpaper long enough to smooth the bottom of the cone. It was then dipped in a small amount of a paste mixture of fusible red clay and set immediately on the green, unburnt tile. The tile immediately absorbed the moisture in the slip and in five minutes it was perfectly safe to set in the kiln. In that way the cone was cemented to the tile by the use of a minimum of moist material and the cones were always the same height above the tile.

Mr. Hull: Did you find any difference with the boiling in that case, or did it do away with the boiling?

Mr. Ogden: I think it did. The amount of cementing mixture was very small, indeed, and when fused

amounted to no more than a film like a glaze, cementing the cone to the tile.

Mr. Hull: Did you have any trouble with the boiling?

Mr. Ogden: None at all.

NOTE ON THE FLUXING EFFECT OF THE ADDITION OF CLAY TO CONE MIXTURES CONTAINING LITTLE OR NO CLAY.

BY

L. B. COULTER, Columbus, Ohio.

The theoretical R_2O_3 equivalents of the cones numbers 1 to 010 are kept constant at

$$\left\{\begin{array}{l} 0.3\ Al_2O_3 \\ 0.2\ Fe_2O_3 \end{array}\right\}$$

In cone No. 1, of the formula

$$\left.\begin{array}{l} 0.3\ K_2O \\ 0.7\ CaO \end{array}\right\} \quad \left.\begin{array}{l} 0.3\ Al_2O_3 \\ 0.2\ Fe_2O_3 \end{array}\right\} \quad \left\{\begin{array}{l} \\ 4\ SiO_2 \end{array}\right.$$

the alumina is all introduced in the form of feldspar and in cone 010, of the composition:

$$\left.\begin{array}{l} 0.3\ K_2O \\ 0.7\ CaO \end{array}\right\} \quad \left.\begin{array}{l} 0.3\ Al_2O_3 \\ 0.2\ Fe_2O_3 \end{array}\right\} \quad \left\{\begin{array}{l} 3.5\ SiO_2 \\ 0.5\ B_2O_3 \end{array}\right.$$

only 0.05 of the alumina is brought in as feldspar, the remainder being derived from clay. In order to obtain a cone which melts just harder than cone No. 1 the alumina is increased at the expense of the ferric oxide. This means that clay is introduced, which is absent in this mixture, while the cone numbers which are more and less fusible contain more and more of clay as they recede from cone 1.

In making cone compositions, as manufactured by Prof. Orton, any mixture which proves too fusible is made harder by the addition of a mixture of clay and flint which are blended in such a ratio that if added in the proper proportion they will produce any cone formula between cones 4 and 22. This mixture is composed of one equiva-

lent of clay and 8 equivalents of flint, making the composition $Al_2O_3 10SiO_2$.

In attempting to use this mixture of clay and flint in a batch of cone 1 stock that was found to be a little too fusible, the results attained were entirely opposite to what was expected. Instead of decreasing the fusibility the mixture was made still more fusible. Feeling confident that, if the additions of the clay-flint mixture were increased, the proper results would be obtained finally, the increments of clay and flint were continued until the body contained over 20 per cent. of this combination.

The cones made with this composition seemed somewhat more satisfactory in some ways than those made with less clay. The same method of procedure was then tried on some other numbers. The advantages of this change in composition were as follows:

1st. The cones thus made melted more gradually.

2nd. They were not influenced as much as the old cones by sudden and sharp fire, i. e., the old cones would go down sooner in a quick heat than the new ones, but in a steady heat both the old and nex mixtures would go down together.

3rd. The old cones where imbedded in clay would show greater fusibility, while the new mixtures with the clay already added would be less affected in this way.

The fact that greater fusibility was produced by the addition of the clay-flint mixtures was so interesting that it was decided to investigate whether either clay or flint alone were necessary or whether both were needed.

Several series of mixtures were hence made, using in one series clay alone, in another flint alone and in a third a mixture of clay and flint in the same proportion in which it had been used in the cone mixture. The cone numbers selected for these experiments were 1 and 02. These were made of the theoretical formula and the clay and flint were introduced purely as additions.

The results of these experiments showed that the clay was the fluxing agent and that flint hardened the mixture

except possibly on the first addition. In some of the tests the first addition of 0.2 equivalent of flint seemed to increase the fusibility very slightly. The effect of further additions of flint was certainly to harden it.

In the cone 1 series, the addition of clay made the mixture progressively softer until 0.15 equivalent had been added. This made a mixture about one cone softer than the one without any clay. The effect of adding flint together with clay was to decrease the amount of clay which could be added, for producing maximum fusibility, from 0.15 equivalent down to 0.1 equivalent.

The results of the cone 02 series agreed very closely with those of the cone 1 series. Here, again, an addition of 0.15 equivalent of clay produced the most fusible mixture and it took 0.25 equivalent of clay to make a mixture of the same fusibility as the one with no clay. When the clay and flint were added together, the results were again the same as in the cone 1 series. The most fusible mixture was produced with 0.1 equivalent, and 0.2 equivalent made a body equal in fusibility to the one with no clay.

In burning the last series of cones, an interesting feature was noticed which characterizes the behavior of the two classes of cones. At the end of the burn, the cone containing no clay was a little behind the one containing 0.2 equivalent of clay. When the burn was finished the gas was suddenly shut off and the damper closed. This tends to raise the heat suddenly in the muffle in which the cones were placed in the kiln. The body with no clay went down flat in a few seconds, while the one with 0.2 equivalent of clay came down considerably slower. In one case, the fluxing agent was the boracic acid frit used, and in the other place the frit and clay were used together.

Some points that have been noticed in our experience in making cones containing ferric oxide and little clay are:

1st. Reducing ferric oxide from .14 equiv. to .1 equiv. by substituting clay, increases the fusibility. The clay was increased from .034 to .082 equivalent.

2nd. From cone .05 down, the fusibility cannot be increased by adding more clay.

DISCUSSION.

Mr. Orton: I do not want to discuss this paper in detail; but if I had known a few years ago what Mr. Coulter has explained on the board there, it would have saved me some dollars. When we first began making cones, I had the impression that the addition of flint to the cone mixture would certainly increase the infusibility, and I likewise had the idea that clay would do the same thing, either one way or the other. We got into difficulties in attempting to harden up the mixture, which was a little too soft. If we had a mixture low in clay, or none, we had an idea that adding clay would improve its working properties and correct the batch most satisfactorily. We got into trouble all along the line. We found that actually it fused quicker than before it was added. While we ran into this phenomenon in testing the different batches, it was never explained satisfactorily until Mr. Coulter did this work, and I think the end is not yet.

THE MANUFACTURE OF ENAMELED IRON SANITARY WARE.

BY

H. F. STALEY, Uniontown, Pa.

The art of enameling on metal is a very ancient one. Beautiful specimens of enameling have been found dating back thousands of years before the Christian era. For many centuries enamel was used solely for its dcorative value and it was not until about 1825 that the Clark Brothers in England made the first utilitarian enamel ware. This consisted of a line of enameled cast iron cooking utensils.

For fifty or sixty years the business grew rapidly, extending to the manufacture of plumbers' goods, tubs, sinks, bowls, etc. The coating of the cast iron cooking utensils was not a true enamel, being but slightly opaque it was more nearly a glass. The enamel of the first plumbers' goods was made a white opaque by the use of arsenic. This coat was applied like a glaze while the piece was cold, and afterward burned on. About eighteen years ago, following the general introduction of stamped metal, enameled sheet iron kitchen ware replaced the old cast iron ware. About the same time, the dry process of making cast-iron ware such as plumbers' goods was introduced. In the early nineties, tin enamel began to be used in this country.

From that time to this there has been no important change in the method of manufacture of enameled metal ware. The making of sheet iron enameled ware, and that of cast iron enameled ware have grown to be separate industries, differing both in methods of manufacture and in the materials used. It is with the making of cast-iron enameled ware that this paper has to deal. The chief articles made of this material are plumbers' goods, lavatories, sinks, tubs, etc. The method and the materials used

are the same and, for the sake of simplifying the subject, we will speak of the manufacture of ordinary undecorated bath tubs, enameled on the inside only.

The first step in the manufacture of a tub is the making of an iron pattern for the casting. This is a very tedious and an expensive job. Each portion must be filed to such a thickness that the tub will be a thing of beauty and usefulness when finished, but yet will hold the heat right when the enamel is being applied. For instance, the bottom and rim are always made heavier than the sides. How much heavier will depend on the size and shape of the tub and on the furnace in which it is to be fired. Sometimes all the pieces made over a pattern will develop a defect in a certain manner in a certain place. This usually means that a pattern is too thick or too thin at that place. In some cases, it is necessary to use one enamel for the rim, which is a heavy cold part, and a considerably less fusible one for the body of the tub.

The castings are molded in most shops by hand. Two men will make four tubs in a day. Two concerns in the United States, viz., The Standard Sanitary Manufacturing Company and The Kellogg-McCrum-Howell Company, are now molding the castings by machinery. The equipment is very expensive, but the manufactuerrs figure that the increased output may possibly warrant the outlay.

A medium-sized tub has an area of about thirty-three square feet. The average thickness is three-sixteenths of an inch. Such a large, thin piece is rather difficult to cast in a quality of iron that will have the requisite strength, and yet be soft enough to admit of its being machined easily. It has been found that a rather open grained, grey iron gives the best results. Such an iron also offers a fair hold for the enamel coat.

After the casting is made, it is taken to the sand blast room, where the coating of scale and moulding sand is cut rapidly away. From there is goes to the grinding room. Here, by means of emery wheels on flexible shafting, the rough places in the casting are ground down. In

the next room, the filing room, the surfaces that are to be enameled are worked down by files and blocks of emery stone to perfect smoothness. The tub is now ready for the enameling room.

The composition of the enamel is guarded with great secrecy by all manufacturers. The enamels used are soft boro-silicate frits, made opaque by oxide of tin. They are remarkable for the liberal use of fluorides to promote chemical combination and for the accuracy with which they must fit.

The materials for the frit are blended dry with moderate thoroughness and put into a hot frit kiln. The kilns in general use are built similar to the ordinary potters' frit kiln but larger. Some of them take thirty-three hundred pounds at a charge.

They are simply large boxes with inclined bottom and arched roof. The raw material is fed in from the top or one side, and drawn off continuously or periodically from the lower part of the floor. The heat is obtained from a flame which is led across the kiln just beneath the roof. Various attempts have been made to build frit kilns that would be heated from below, without the combustion gases coming in contact with the frit, but no material has been found which will transmit the heat readily and yet resist the intensely corroding action of the molten frit. The bottoms are generally made of refractory clay blocks, six or eight inches thick, and these have to be replaced every few months owing to the frit eating down through the joints. The writer has seen half of a fire brick of good quality eaten away in three months.

The temperature of fusion varies with different factories. It will range from 1,000° to 1,100° C. The temperature of fusion of the frit has no direct relation to its remelting point when used as an enamel. As the molten frit comes from the kiln, it is quenched in cold water, and then dried, usually on a hot plate heated by waste heat from the frit kiln.

If the enamel is for a ground or slush coat, feldspar,

clay, flint or other material is added to make it more infusible. If it is a cover enamel, it may have a few additions made to it, usually in the shape of supplementary opacifying agents. The material is then fed to the grinding mills.

The mills used for grinding are periodic ball mills. Some plants use a number of small mills, some prefer large mills holding sixteen hundred pounds. The grinding is always done dry. The product is not sieved, but must be a powder free from any palpable grit, passing approximately a two hundred mesh sieve. After grinding, if the material is a slush coat, it is mixed up with water to the thickness of paint. If it is a cover enamel, it is ready for the enameling room.

The enameling room is usually a large rectangular room with furnaces built along one side. The furnaces are large ovens, about nine feet long, by six wide, by five high, inside dimensions, with an arched roof and a wide door at one end. If coal is used for fuel, the floor, sides, and arch are built double, forming a tight muffle. If natural gas is used, the inner arch is sometimes omitted, thus making a semi-muffle.

In front of each furnace is a table or rack for holding the tubs while they are being dredged or coated with enamel. These are fitted with gears, so as to admit of their being tilted or revolved in almost any direction. Near by, suspended from a derrick, is a large two-pronged fork used for lifting the tubs in and out of the furnace. The prongs of the fork are about seven feet long, and the handle about twenty. Three men generally work at a furnace; two handle the tubs and apply the enamel, while the third revolves the table, and opens and closes the door of the furnace.

When a tub is to be enameled, it is brushed out with a soft brush or washed out with water to remove any dust that may have lodged on it, and splashed with a couple of dipperfuls of slush enamel. The sides of the tub are hammered vigorously with wooden mallets, and the excess

slush drained off. The very thin coat of slush remaining is dried by setting the tub close to a hot furnace for a few minutes.

When the slush is dry, the tub is caught up along the under side of the rim by one of the large forks, and placed in the furnace. In from seven to twelve minutes the iron is a bright cherry-red and the slush has melted evenly over the ware. The piece is quickly withdrawn and placed on the revolving table. One man sifts enamel on the rim through a small sieve on the end of a long handle, made to vibrate by the enameler beating on the handle, while the other man dredges the sides and bottom. The heat of the iron fuses the enamel enough to make it stick to the surface. In about three minutes, the piece is thoroughly covered, and is immediately put back into the furnace. In a few minutes the enamel has melted down smooth, and the tub is drawn and given another coat. This runs smooth in a few minutes, and the tub is given its third coat and allowed to bake. It is then drawn and allowed to cool.

The proper enameling of a tub is a matter of considerable skill and judgment. Each dredge must be evenly distributed over the piece. If it is too thin in places, blue spots will show on the finished ware; if too thick, crazing or chipping off of the enamel is liable to occur. One fault especially difficult to avoid is the tendency of the enamel to run and collect in rolls or beads at certain points. This spoils the appearance of the piece and is very liable to result in crazing when the tub cools down.

The temperature at which practically all tub enamels mature is very close to 1000° C. It dare not be much higher, for between 1050° and 1100° C. cast iron burns "dead," becoming exceedingly weak and brittle. It cannot be much lower, on account of the increased cost. An enamel that would mature much earlier would have to be considerably higher in the more expensive fluxes. Another important consideration is that an enamel that would mature much earlier would be a softer silicate, more easily soluble and more liable to deteriorate under ordinary con-

ditions of use. An enamel for cast iron can be made at 1000° C. that will meet all the requirements of the service for which it is intended.

Though the enamel matures at 1000° C., the furnace is fired to a considerably higher temperature. It is kept down by the process of enameling. Every thirty minutes, or thereabouts, a cold tub weighing 300 to 450 pounds is put in, heated to 1000°, drawn out three times, allowed to cool considerably, and heated up again after each cooling. This process keeps the furnace and the men busy, ensuring a maximum output of ware, but it calls for skill and watchfulness on the part of the enameler. Each coat of enamel is baked very quickly; it is melted down in from two to five minutes in a rapidly rising heat. A minute too long in the furnace during any one of the four heating periods may ruin the piece. The defect may be burning up of the slush coat, sulphur bubbles, running off of the enamel, etc. If the tub is not heated sufficiently, the result will be pin holes in the coldest parts, and a rough, uneven coat, of poor luster.

The temperature range of a good enamel is not as narrow as it would seem at first thought. A variation of forty to sixty degrees C., two or three cones, may take place in a very few minutes under the conditions described. The range is however certainly more narrow than that of a pottery glaze. The baking-on of an enamel is the remelting of a homogenous silicate, or mixture of silicates, with very little chemical activity. The maturing of a glaze on a body involves its production, by means of chemical activity caused by heat between the various ingredients of the glaze and between these and some of the ingredients of the body, resulting in a silicate, or mixture or silicates, more or less homogenous in composition. In the case of an enamel made in a periodic frit kiln, the ingredients are carried to complete fusion and chemical combination is fairly complete; the material having been still further blended by fine grinding in a ball mill, the re-

melting can be done very rapidly, and still result in an extremely homogenous product. In case of a glaze, the composition will never be entirely homogenous, even though part of it is fritted. The blending of the glaze, the blending and manufacture of the body, the application of the glaze, all of which are mechanical processes, and the heat treatment, which is a chemical process, are important variables.

Of course the test of the composition of the enamel comes when it is applied to the iron. The function of the slush coat is, first, to cover the casting while it is heating up the first time so as to prevent oxidation and, second, to form a close mchanical and probably chemical union with the iron which the cover enamel, heavily laden with insoluble matter, would not be able to do. Being so extremely thin, and merging into the iron and the cover enamel, its co-efficient of expansion is not a material factor. The requirements of a good slush are that it run thin on melting, so as to take a good hold on the iron, and that it will not volatilize readily, or burn "dry."

The cover enamel must fit the iron accurately, both as to melting point and co-efficient of expansion. A slight difference in co-efficient will result in crazing or shivering and chipping off of the enamel. I have known an addition of ten pounds to the amount of flint used in a mix of six hundred pounds to make all the difference between a smooth, nice working enamel and a rough comparatively infusible one that chipped badly. In a general way, it may be said that the composition being about right, an enamel that is too soft will craze, and one that is to hard will chip or shiver as potters say.

The test that an enamel has to stand is certainly severe. As stated before, the tubs are drawn at a temperature of 1000° C., 1800° F., when the iron is at a bright cherry-red and the enamel is in a viscous condition, and allowed to cool in the open air. No especial trouble is taken to protect them from drafts of cold air. After this ordeal there is little danger that the enamel will develop

defects of crazing or shivering after leaving the plant. In fact, the whole process of manufacture is such as to develop any possible defects in the making, and to give assurance that they will not show up after the ware leaves the plant.

After the tub is cold, it is carefully inspected as to defects in application and fit of the enamel, color, luster, etc. Minute crazes are readily detected by rubbing the surface with a rag filled with black grease. The tub is then painted, supplied with feet and fittings, and taken to the ware room.

The losses are quite high. It is a subject hard to get at accurately, as the manufacturers are naturally reluctant to give information pertaining to this point. They will run from 5 to 25%. In the same way, the subject of costs and profits is kept more or less secret. It may be said, however, that the profits are not nearly as large as people not conversant with the business imagine. Twenty years ago a tub sold at the factory for forty to sixty dollars, and cost probably two-thirds of the selling price. Today, owing to cheapening of the processes of manufacture, and to the fact that the business is more or less overcrowded, an ordinary plain tub will sell for twelve or fourteen dollars at the factory in carload lots. Some of the factories are making money, some are making a living for their owners, and some are like elephants, whose owners would be glad to get rid of them if they could. If a factory is successful, the profits are about the same as those in the face brick business, but the investment is much greater and the chances of success much less.

ROCK DECOMPOSITION AND CLAY FORMATION IN THE LABORATORY.

BY

ALLERTON S. CUSHMAN, Washington, D. C.

In spite of the discussion which has been going on for many years in the effort to account for the peculiar physical characteristics of clays, it is safe to say that all clays are directly or indirectly products of rock decomposition. Possibly we may go farther and agree to define clay as any finely divided deposit found in nature, in which the predominating and essential constituent is a hydrated silicate of aluminum. In certain kinds of analysis of earthy deposits it has been the custom to designate as clay the finer portions that can be separated by elutriation, or other mechanical means, while the coarser particles are referred to respectively as silt, sand, and gravel. While this classification may be convenient, it is undoubtedly in many ways misleading if not incorrect. Quartz sand does not become clay because it is a fine state of subdivision, and the same thing may be said of many other fine-grained mineral deposits. Whether residual or sedimentary in nature, the basis of all clays is a hydrated aluminum silicate. A very large proportion of what I prefer to call the soft surface of the earth, exclusive of water, is made up of more or less hydrated silicate, a decomposition product of the original hard or rock crust.

Averages which have been made from the chemical and petrographical analyses of a great number of rocks indicate that the feldspars constitute about 60 per cent. of the entire rock crust of the earth, and it is undoubtedly to these feldspars and more particularly to the orthoclases that we must look for the raw material from which nature makes our clay bodies. It has been frequently asserted in numerous text-books and other publications that the kaolinization of feldspar is promoted by the occurrence

in ground and surface waters of various acids of both organic and inorganic origin, while the fact that under certain conditions pure water suffices for carrying on the decomposition has been largely overlooked. Such assertions are unfortunately too often based upon an opinion as to what ought to take place, rather than upon experimental evidence as to what actually does take place. It is, of course, a fact that some of the natural silicates are easily decomposed by acid solutions, but in the case of others, quite the reverse of this is true. It is now well known that glass (which is after all merely a particular state of equilibrium under certain conditions, between the same bases which exist in nearly all rocks, and the acid oxide, silica) is much more readily decomposed by pure water than it is by acid solutions. Evidence is now accumulating to show that the same thing is true of many of the rock-making minerals.

It has been my opinion for a long time past that the most hopeful way of gaining information in regard to the formation, structure and characteristics of clay is by carrying on, if possible, the kaolinization of orthoclase in the laboratory within a reasonable length of time. A considerable measure of success has attended these efforts, and although the work is not yet ready for detailed presentation, some account of it may prove of interest at this time.

Probably the greatest aid to man's knowledge of the physical structure of various forms of matter is furnished by the microscope, and therefore it is most natural that the student of the useful properties of clay early turned to this instrument for information. We are obliged to confess, however, that microscopic investigations have taught the student of clay structure very little. While one clay appears rich in plate-shaped particles, consisting of tiny crystals of kaolinite and other materials, another appears to show an almost entirely amorphous aggregation of particles more or less rounded or spherical in shape. The bacteriologist and pathologist has had some experience in the limitations of the power of the microscope to answer

vexed questions in his own special field of research. There are diseases known which observation indicates are due to specific pathogenic germs, and still the most powerful microscopes have failed to reveal their presence. For this undoubted fact there can be and has been but one explanation offered, and this is that the thing sought is submicroscopic in size. Is it not possible that the physical structure of clay particles, which leads in one case to plasticity and in another to a lack of plasticity, is in a similar manner submicroscopic in magnitude? It is quite certain that many plastic clays behave as if the particles were capable of absorbing various substances into a net or web-like system of pores. One thing is at all events certain, and that is that all plastic clays consist of more or less hydrated particles, and if the clay is dehydrated at a sufficiently high temperature, plasticity is destroyed. Finely ground charcoal is believel to consist of finely porous particles, but it is not hydrated and is not plastic, therefore we must infer that submicroscopic porosity is not the cause of plasticity, but rather a condition which possibly accompanies it. It has been pointed out by the writer in former publications that there is evidence to show that this web-like condition, as indicated by their absorptive power, is characteristic of colloid or pectoid particles and not ordinarily of crystalline particles.

The method of carrying on the kaolinization of orthoclase in the laboratory, which has already been outlined in an official publication, (*a*), is briefly as follows: A sample of orthoclase is first ground in a pebble or tube mill until the powder passes a 200 mesh screen. It is then slimed with distilled water until it has somewhat the consistency of a thick cream, and the slime is placed inside an ordinary unglazed clay cup or cylinder such as was formerly used for certain types of bell batteries. An ordinary arc light carbon is then inserted and the clay cup set down inside a cylindrical glass vessel containing distilled water. An-

(*a*) Circular No. 38. Office of Public Roads, U. S. Dept. Agr.

other carbon electrode is then inserted in the outside compartment. The apparatus is shown in Fig. 16. The cell is connected with a direct current of about 110 volts, the inner or slime chamber being in connection with the positive pole. With about 200 grams of orthoclase, the amount of current passing rarely exceeds 0.05 of an ampere. As

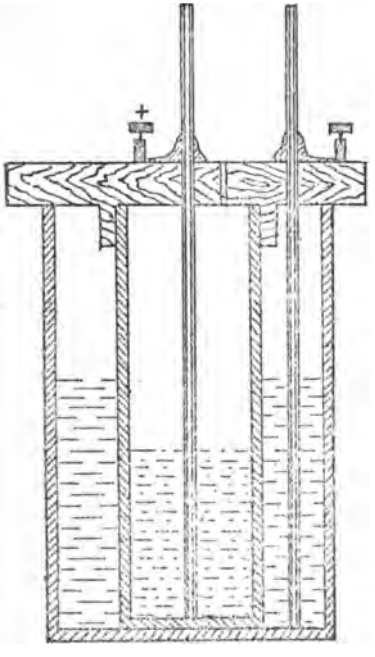


FIG. 16. Electrolytic cell.

the current passes, the level of the water in the anode or slime chamber falls, owing to the passage of liquid through the porous septum, while at the same time the clear filtrate which is accumulating in the cathode chamber will be found to be growing alkaline at the expense of the potash in the orthoclase powder. The passage of liquids through permeable diaphragms under the influence of an electric current is known as electrical endosmosis and was studied

(*a*) Ann. Phys. (Poggendorff), 1852, 87, 350.

by Wiedemann in 1852 (*a*). As far as the writer is aware, however, this is the first effort to use the principle in the investigation of rock decomposition. If finely ground orthoclase is digested in water a small amount of potash passes into solution, but the reaction soon comes to an end. If the sample has been dry ground no more than about 0.03 per cent. of alkali can be extracted by leaching with water. If the grinding has been done wet the decomposing action of the water goes farther and from 0.3 to 0.4 per cent. of the alkali can be obtained by electrolysis. The method which we are now following in our investigation is to electrolyze the slimes obtained by grinding orthoclase in laboratory pebble mills until the yield of alkali becomes very small. The charge in the slime chamber is then removed and reground for several hours, when it is again transferred to the electrolyzer. Starting with a sample of orthoclase containing originally 11.4 per cent. of alkaline bases, it has so far been possible by this method to extract 3.6 per cent., or about one-third of the total alkali present, in fourteen grinds. As the extraction is still going on it is hoped that in the end it will be found possible to carry this artificial kaolinization to its definite conclusion, under the action of distilled water alone. As the kaolinization proceeds we should naturally expect the sample to become more and more clay-like. This has undoubtedly taken place, although a full description of the result must be deferred until the investigation is more advanced.

The percentage of potash extracted on each of the fourteen runs on two separate samples, as described above, is shown in the following table:

TABLE I. — *Alkali Extraction from Orthoclase Powder by Electrolysis.*

Orthoclase powder.	Ground. Hours	Total Alkali Extracted, Calculated in Per cent. K_2O.	
		Sample No. 1242.	Sample No. 1300
Original sample 200 mesh.....	.....	.15	.14
Reground dry in mill.....	2	.19	.22
Reground wet in mill.....	2	.41	.15
" " "	2	.13	.14
" " "	6½	.23	.26
" " "	6½	.19	.21
" " "	6½	.16	.17
" " "	6½	.18	.25
" " "	2	.12	.15
" " "	12	.45	.35
" " "	24	.46	.41
" " "	12	.43	.27
" " "	24	.39	.45
" " "	24	.40	.40
		3.89	3.87

The original charge of orthoclase taken was 200 grams. After electrolyzing until the yield of alkali begins to be small, the slime is removed from the apparatus and reground in the pebble mill. Another electrolysis is then carried on and the kaolinization thus proceeds by successive stages, as shown in the table. It is at once apparent that in order to make this a continuous process it would be necessary to arrange an apparatus that would carry on wet grinding and electrolysis at one and the same time. So far no such piece of apparatus has been devised. A simple arrangement which may appropriately be called an electro-dialyzer, has been in use for some time in the writer's laboratory and demonstrates after a fashion the continuous kaolinization of orthoclase. In the apparatus

which is shown in Fig. 17, A is an ordinary tin can of one gallon capacity, to which an electrode and binding post G is soldered. C is a porous clay pot closed at the top by a tight cork or stopper, H, through which a platinum electrode F, passes. B is the slime compartment. At the

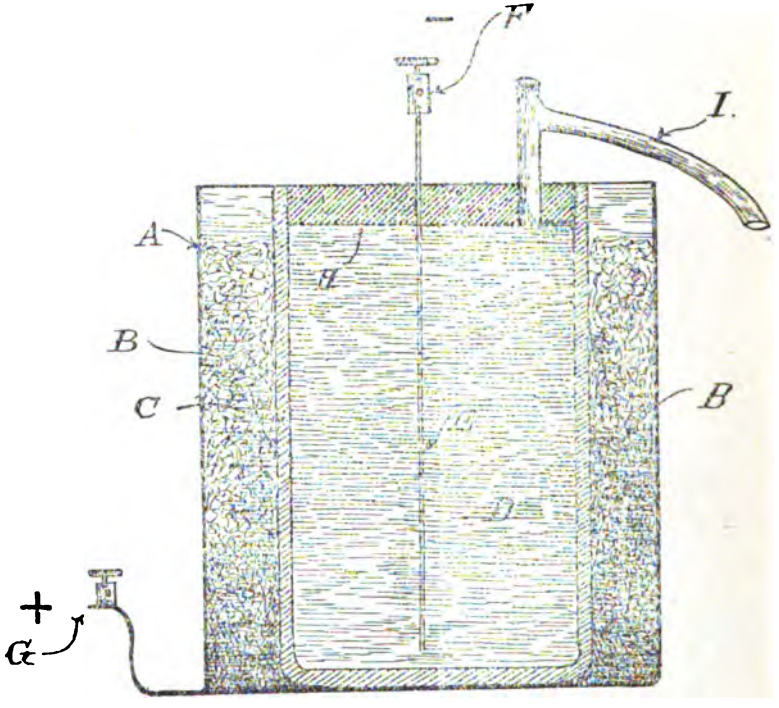


FIG 17. Electro-Dialyser.

beginning of the run the compartment D is entirely filled with distilled water and 3 kilograms of ground orthoclase is placed in B. Upon starting this apparatus the first 100 cc. that come over are not especially rich in alkali, owing to the fact that the electrolysis is begun with distilled water on the inside of the cup. The succeeding effluents become stronger, however, until a certain maximum is reached which is maintained for some time. This is shown

in the following table, in which the results of the titrations of the first six hundred cubic centimeters collected are shown:

TABLE II. — *Extraction of Potash from Orthoclase.*

1st	100 cc. = 7.8 cc.	N/10	HNO_3	= 0.044 gm.	KOH
2nd	100 cc. = 18.7 cc.	"	"	= 0.105 gm.	"
3rd	100 cc. = 32.2 cc.	"	"	= 0.180 gm.	"
4th	100 cc. = 31.6 cc.	"	"	= 0.180 gm.	"
5th	100 cc. = 32 cc.	"	"	= 0.180 gm.	"
6th	100 cc. = 31.5 cc.	"	"	= 0.180 gm.	"

This action proceeds until about 13 to 15 grams of potash (K_2O) equivalent has been extracted, equal to about 0.4 per cent .of the weight of the rock powder taken. Towards the end, the effluents become weaker in alkali, but so far the point has not been reached at which the extraction of alkali entirely ceases. If the slime is removed from the slime chamber and reground wet in a ball mill the extraction starts off again with renewed vigor. When first started the alkaline effluents come over with considerable rapidity, only a few minutes being required to collect 100 cc. Later on, however, the pores of the clay cup appear to clog and the endosmosis slows up. By removing the cup, drying out and cleaning it, the rapidity of the action is in part restored.

It is apparent that in these experiments it is necessary to obtain porous cups which shall possess the right degree of porosity and at the same time be practically free in their body composition from all soluble alkaline bases, such as lime, magnesium, soda, and potash It has been our custom to run the cups blank with distilled water until they are free from the last trace of soluble bases.

For the most part our work has been done on samples of orthoclase which were quite free from lime and magnesia and which carried only potash and a little soda as the soluble bases. Owing to the difficulty experienced in obtaining pure clay cups our very latest experiments have been made with wooden cups from which the resins have

been previously extracted with ethyl alcohol. The small amount of potash which is stored up in wood fibre and which appears in the ash does not appear to affect the results sensibly. Only white pine and poplar wood have so far been tried, and although these wooden cups work quite as well as clay, as far as the extraction of the alkalies is concerned, a curious fact has been noted. There is at no time the slightest change of level of the liquids on either side of the wooden septum, or in other words, endosmosis does not take place. The only explanation that can be offered for this phenomenon at the present time is that the pores in the wooden septum are of a different nature from those in the clay and do not permit endosmosis to occur.

We may now turn in conclusion to the discussion of the results thus far obtained. Summarizing the facts, they appear to be as follows:

(1) If ground spar is mixed with water, the water exerts an immediate decomposing action on the material, as can be seen if a little phenol phthalein indicator is mixed with the water.

(2) Although this action takes place quickly it does not appear to proceed far, for if the slime is filtered no more than .03 per cent. of alkali can be detected in the clear filtrate, if orthoclase has been used.

(3) By electrolysis as much as 0.4 per cent. can be obobtained by one grinding.

(4) After 0.4 per cent. has been extracted by electrolysis, the action slows down but does not entirely cease. Small amounts of alkali appear at the cathode on each subsequent run, showing that the decomposing action of the water does not entirely cease.

(5) By alternate grinding and electrolysis it has so far been found possible to extract 4 per cent. of the soluble bases out of a total of about 11 per cent. present at the start.

(6) There is no reason to believe that the action cannot be continued to the complete kaolinization of the feldspar.

Although the interpretation of these results should properly be put off until the work is more complete, several interesting questions present themselves for discussion. Are we indeed carrying on the kaolinization of feldspar by a process which is in the slightest degree analogous to that which is operative in nature? Brogniart (*a*) surmised that electrolysis may take place in nature, owing to the establishment of local differences of potential on the earth's surface, and thus lead to rock decomposition. It is a well known fact that colloid precipitates prepared in the laboratory are capable, if negative or acidic in their nature, of absorbing and holding alkaline bases; it has been shown that this is also true of many clays. (*b*) Precipitates which have absorbed bases can be made to give them up by treatment with solutions of certain electrolytes, like ammonium salts; it has been shown that this is also true of clays and wet-ground rock powders. It has further been found that if colloid precipitates that have absorbed bases are subjected to electrolysis, the bases are again set free; it now appears that this is also true of rock powders which have been acted upon by water.

The evidence seems almost conclusive as to the fact that clays and more or less decomposed rock powders owe their plasticity and binding power to the presence of colloid matter. This does not mean that matter is present that is capable of going into solution in the same way that common glue is. The point is that matter exists in a hydrated, softened and non-crystalline condition. The writer has suggested the word "pectoid" to replace the word colloid, in order to avoid the confusion occasioned by the association of the latter word with the dialysis of solutions through parchment membranes. In this connection it is of interest to point out that Rohland (*c*) has shown by means

(*a*) Merrill, Rocks, Rock-weathering and Soils, p. 175.

(*b*) Bull., 92 Bren. Chem. Dept. Agr. and Circ. 38, Off. Pub. Roads, Dept. Agr.

(*c*) Zeit. Electro. Chem. (1905), 11, 455.

of an interesting series of experiments that plastic clays contain colloidal constituents, which he assumes to be partly of organic and partly of inorganic origin. The fact that the admixture of freshly precipitated alumina, aluminum silicate, or silicic acid with a lean clay does not give it all the properties of a plastic clay has been thought by some investigators (*a*) to upset the colloid theory. Such reasoning does not, however, seem valid, as both plasticity and binding power can be shown to be due to a softening or decomposing action of water on the surface of fine particles, which is invariably increased by the action of wet grinding, pugging, and puddling.

The investigation described in part in this paper indicates a method by which the rate of rock decomposition and clay formation under certain given conditions can be studied in the laboratory.

I may further say that I have never found orthoclase that did not have some of its potash replaced by soda. Orthoclase passes by continuous gradations into other kinds of feldspars such as the plagioclases. For the sake of discussion, however, we may consider what takes place when water acts on finely ground orthoclase. Orthoclase may be considered as a double silicate of aluminum and potash. Now it is probable that this double silicate is slightly soluble in water in the same sense that sugar is, but immediately upon solution a decomposition takes place with the deposition or precipitation of the more insoluble simple silicate of aluminum. The potassium silicate which remains is a soluble substance and it would appear that the potash should pass freely into solution. This, however, it does not do, as the potash is held by absorption in the colloidal aluminum silicate.

Considering the potash alone it can be seen that there are two tendencies at work, one towards solution and the other towards absorption. Electrolysis does not produce decomposition of the double silicate, but it aids the action

(*a*) Grout, Jour. Am. Chem. Soc. (1905), 27, 1037.

of the water by overcoming the tendency of the potash to be absorbed in the colloidal decomposition products. This is the interpretation I am led to. The extent of the decomposition which takes place when water acts on finely ground feldspar has been underestimated because investigators have measured it by the amount of material passing freely into solution. For the reason stated this is incorrect and it is apparent that electrolysis provides a method of studying the actual amount of decomposition which takes place. The results of these studies led me to make a suggestion somewhat foreign to the immediate object of the research. It seemed possible that in as much as the feldspathic rocks in the state of fine powders undoubtedly undergo more decomposition than has been previously expected, that they might be used as fertilizers under proper conditions. It appears that this possibility has presented itself to several agricultural chemists in the past and some interestiing experiments have been made in crop growing with ground feldspar as a potash fertilizer. It is probable, however, that this is the first quantitative study that has been made of rock decomposition in which the method of electrolysis has been employed. There can be no doubt that more of the potash in feldspar is made directly available under the action of water than has been heretofore believed.

DISCUSSION.

Mr. Orton: I will ask Dr. Cushman whether in the repeated grindings he is compelled to make, he thinks the dust from the ball mill enters into the potash-bearing material he is at work on? Do you think that acts as a source of contamination?

Mr. Cushman: Possibly it does. It is very hard to do this work without some contamination. The greatest annoyance we have to contend with is from the dust in the air which contains, of course, sodium chloride and which finds its way into the apparatus. All this interferes with the accuracy of the work. It is impossible to keep this sort of apparatus perfectly clean. We know, however,

what to expect from different kinds of rocks, and though our results may not be absolutely accurate there can be no doubt that the major portion of the alkali obtained is extracted from the rock powders.

Mr. Barringer: How do your results agree with Daubrée's?

Mr. Cushman: The results were in essential agreement with Daubrée's figures.

Mr. Barringer: I have tried at one time separating the potassium chloride from sugar juice by means of a glass tube apparatus, containing a membrane in each arm, the potassium hydrate going one way and the hydrochloric acid the other. It worked fairly well. I wondered whether it would not be possible to use in Dr. Cushman's work some kind of a grinding apparatus in conjunction with the electrolytic separation so that most of the alkali could be removed.

Mr. Cushman: I think something of that kind might be practical. I have not had time to try to devise apparatus. But even if we could do that, I think it would be a very expensive operation. We considered a revolving electrode in the slime chamber, putting in sharp sand as an abrasive and running at a high rate of speed; our idea was to see whether the sharp sand would not do the grinding and at the same time the slime would be subject to continuous electrolysis. Some such method might be made into a continuous process.

Mr. Barringer: You were speaking of a porous cup, — how would hydro-silicate of lime do? It makes a good filtration cup.

Mr. Cushman: I used to believe that such silicates were insoluble in water. I am afraid now that a composition of that sort would be giving the lime off all the time, though perhaps very slowly. It is more convenient if we have the porous cup absolutely free from bases that are alkaline, so that when the alkalies come through it means they come from the rock powder.

Mr. Barringer: Does the product of this forced decomposition of feldspar resemble real kaolin?

Mr. Cushman: I must say that the residues left after the alkalies have been removed do not exactly resemble clays, but you must remember this is not exactly the process which nature is using, because at the same time kaolinization is taking place in nature, the material is undergoing lateral pressure, if not cubical compression. The action goes on more slowly and there is no chance to grow spongy in the way these products do. If this process were carried on more slowly, under great pressure, we might be able to make something like clay. To some extent the residues do comport themselves like clay. The binding power is increased, the ordinary spar having none to speak of. The product has considerable binding power, and is more plastic, as far as we can judge that quality. The raw material would mould no more than sand. But this stuff which has been electrolyzed and four per cent. of alkalies taken out is much more claylike. If it is wet with water and moulded, it maintains its form when it dries out. It has some binding power.

Mr. Stover: Have you made observations as to the action under different degrees of heat, extreme cold, below zero, and up to about 90° F.? I am asking this because the conditions in the earth vary with winter and summer. Again, have you tried it in continued light, as against no light?

Mr. Cushman: We have tried all degrees of temperature of the laboratory; but since we found so little difference in the action of the water under these different temperatures, we never thought it worth while to try it at a colder temperature. I do not think it would increase the action. As to the effect of continued light, of course I am aware that a great many reactions are influenced thereby, and perhaps this would be. You must remember that while the amount of alkali we get out can be estimated easily, at the same time the amount is very small and

if light did produce a slight difference we could not estimate it. We cannot even get a pure porous cup, or if we do get it pure, we can't keep it so. We cannot keep the dust out entirely.

Mr. Stover: Could you not guard against it by a hermetically sealed chamber?

Mr. Cushman: We have not gathered all the detailed information we want, and which it will take years to get. This may be said to be a report of progress, and we have not solved all the questions by any means. It would take a long time to do it, if we had nothing else to do. But there are other things to claim our attention beside research work.

Mr. Burt: It is certainly very amusing to all of us to hear Dr. Cushman apologize for this splendid paper. It occurs to me that it is a somewhat similar case to the problem of acetylene gas manufacture; when they first began using carbide, the deposit of hydrate on the carbide served as a shield.

I can readily see the possible electrical action on the earth's surface and the leaching out of such soluble alkalies as are there present; but I do not quite see how you are going to get at the equivalent of what you have in the re-grind, as the orthoclase lies in its bed. How are you going to mechanically eliminate this coat of deposited kaolin as it probably forms on your orthoclase crystal, without calling in the action of friction or motion?

Mr. Cushman: Although nature has carried many of these decompositions to the end long ago, the case is very rare where there isn't a little potash left in a clay. In nature, then, why do not the clays contain more potash; and how does it get out if held by the products of decomposition? I admit that it is pure speculation; I was not the first to indulge in it, whether or not electrolysis has had something to do with clay formation. Mr. Burt's question is a very pertinent one.

Mr. Stover: At one time, for the sake of economy, we were using the same water over and over to make our

slip. After awhile we began to get a scum on the ware. We investigated for the purpose of getting rid of the scum, and I found we were getting quite a considerable amount of potash in solution, and this we were able to overcome by the use of fresh water. While in this instance we eliminated the difficulty, it occurs to me that in using water from an unknown source, or of unknown composition, potters are taking risk and getting into difficulties which might be avoided by learning the nature of the water being used, and if not right, seeking another source of supply.

Mr. Yates: I will ask Dr. Cushman what connection there is between his mechanical process and the old practice of grinding the material on an elevated spot, exposing it to the weather and allowing the potash to wash out naturally, and thus increase plasticity? Of course, this is a little out of my depth, but I would like to know whether this has any connection with the old way of weathering clays.

Mr. Cushman: I think that is a good point. I do not think electrolysis has anything to do with the increase of plasticity in the clays during the weathering process. I was discussing electrolysis in its relation to aiding, not carrying on, the kaolinization of orthoclase. I did not say it could not take place unless there was electrolysis. Those curves do not touch the zero point (referring to chart); kaolinization takes place all the time. But electrolysis hastens the reaction by leading away the decomposition products.

Take a little plastic clay in an air dry condition, make up a solution with potassium chloride, put the clay in and shake it up, filter it through paper, then analyze your filtrate, and you will find some of your potash has disappeared. Where has it gone and why has it disappeared? The potash has gone into the clay structure; the bases have been absorbed by the clay. What does this mean? It means that something in the clay has a tendency to draw into the clay the bases while water has a tendency to leach them out. It is like a "tug of war" between

two forces pulling in opposite directions. In spite of the fact that potash has a tendency to go into solution, some of the potash has gone out of the water into the clay. Does this not show that the pull of the clay structure is stronger up to a certain point in the equilibrium than the pull of the water in which it is dissolved? It certainly means that the clay structure has absorptive power.

As long as water is acting on orthoclase, it is coming into equilibrium and the potash is being removed. If fresh water keeps on coming, each time there will be equilibrium established, the water will pull out some of the potash, but the decomposition product will pull the other way. The equilibrium is always changing in favor of slowing down the action. It may be that the pull gets stronger in the direction of solution, so that finally if we get clay without any potash in it, some other action has helped the water in taking the potash away.

If you assume that electrolysis is taking place, you can see how it works in favor of the solvent action of water. Since potash salts are dissociated in water, and carry large static charges of electricity, it stands to reason that they will be repelled by like charges and attracted by unlike charges. It has been shown that a colloid substance is negative in its nature, therefore potash ions carrying positive charges should be drawn towards negatively charged colloids. I do not know to what extent it has been accepted that there are colloids in clay, but all these things hang together and point in the same direction.

I may say that the weak point of the colloid theory is that we are not yet able to precipitate a colloid like aluminum silicate in the laboratory, and mix it up with a non-plastic clay and produce the wonderful properties of clay dug out of the pit. As I have pointed out, colloids are formed much more slowly in nature under temperature and pressure conditions we cannot imitate. These colloids, if properly produced in the laboratory, do in a way increase plasticity and binding power. But with clay, no matter how many times you dry it out and

wet it again, it can be worked. That does not apply with colloids prepared in the laboratory. If dried out in the air, they do not work up nicely again in the way that natural clays do. Because we cannot exactly imitate nature's method of clay formation is no reason why we should not study and understand the method.

NOTES ON THE RATIONAL ANALYSIS.

BY

CHARLES F. BINNS, Alfred, N. Y.

No one can read the state reports and other writings on clays and the clay industries without finding that upon one subject at least there are wide variations in opinion. "When doctors differ," asks the proverb, "who shall decide?" and most assuredly, on the subject of rational analysis, there is great divergence of thought.

Seger expresses no doubt as to the effect of the process generally employed. He gives it an unqualified approval, stating that it "removes the amorphous and hydrated silicic acid obtained in the decomposition of the clay-substance completely, while the admixed quartz and feldspathic detritus remain unaltered," and in another place he says that "the fragments of orthoclase and quartz are hardly attacked at all."[1]

Langenbeck in discussing the same question,[2] quotes from Böckmann to the effect that in two cases 18.56% and 16.05%, respectively, of orthoclase was dissolved by the rational analysis method, and, after confirming the figures in an experiment of his own, he goes on to say: "It is hardly possible then to dissolve the clay-substance out of a clay without loss of feldspar, which may reach 20% of the amount present."

Ries says:[3] "The finest particles are known as the clay-substance, which may be looked upon as having the properties of kaolinite," and again, "Mica may practically be considered as kaolinite for the reason that there is usually so little of it and also because the experiments of G. Vogt have indicated that it acts very similarly to kaolin."

Stull says:[4] "Mica, if fine enough, exerts a fluxing

[1] Seger's Collected Writings, Vol. I, p. 543.

[2] Chemistry of Pottery, pp. 9-10.

[3] Kaolins and Fire-clays of Europe, p. 22.

[4] Trans. A. C. S., Vol. IV, p. 269.

action upon kaolin and upon ceramic mixtures at temperatures below cone 4."

Buckley and Peppel[5] conclude that the chemical method is unsatisfactory, and decide to calculate the rational composition of the clays from the ultimate analysis.

Jackson[6] advocated the consideration of the composition of the clay-substance, saying: "It is possible to calculate the percentage composition of the clay-substance which will powerfully affect the properties of the clays. In some instances the clay-substance, by reason of the paucity of fluxes, may be exceedingly refractory, while in other cases the clay-substance may be, in fact, the main fusing constituent, being more easily fused even than feldspar."

With regard to the behavior of minerals with reagents, a reference to Dana[7] will show that of all the minerals likely to occur in clays in an unaltered form, biotite is always and glauconite sometimes decomposed by acids. The remainder, including orthoclase, albite, hornblende, and muscovite, are said to be either insoluble or not decomposed by acids. But Dana also states that kaolinite is insoluble in acids. Against this may be set the opinion of Langenbeck[8], where he says: "The dust of these minerals, micas, is practically all decomposed by sulphuric acid," and' using the average percentage of alkali in muscovite as a measure," showing that he considers muscovite to be decomposed, which Dana does not.

The wide discrepancies between the composition of a clay as indicated by the ultimate analysis and that represented in the rational form must long ago have been apparent to investigators, but so far there does not seem to have been any attempt to explain it. Certain questions present themselves here and the endeavor will be made to offer something like a basis of agreement as to the way in which they should be answered.

[5] Clays of Wisconsin, p. 267

[6] Text-book on Ceramic Calculation, p. 57.

[7] Dana, A System of Mineralogy.

[8] Chemistry of Pottery, p 11.

The first question is, "Is kaolinite or clay-substance, having the formula Al_2O_3, 2 SiO_2, 2 H_2O, always the same, except for such variations as may arise from relatively coarse or fine grain, and how far does the difference in grain affect the behavior of the clay?

If this question be answered in the affirmative, alkali can have no place in the clay substance, nor can clay substance be correctly spoken of as being more fusible than feldspar. Of course, it is understood that Mr. Jackson in this allusion referred to the clay substance as represented by the rational analysis method, and the fact that such a point can be made tends to throw the laboratory method into discredit.

A series of experiments herewith exhibited will throw some light on this question. Five body mixes were made up, each having the same rational composition, viz.:

Clay substance	65 per cent.
Feldspar	20 " "
Quartz	15 " "

but five different clays were used. The analysis and rational composition of these clays is as follows, the latter having been calculated from the alkali content simply.

	1	2	3	4	5	6
	Eng. Ball Clay.	Edgar's Fla. Clay.	Tenn. Ball Clay No. 1.	Delaware Kaolin.	Georgia. Clay.	Feldspar.
Silica	54.78	46.37	52.98	48.40	47.04	68.98
Alumina	32.29	39.20	34.26	37.62	39.16	18.82
Iron	.40	.40	.40	.42	.11	trace
Lime	trace	trace	trace	trace	trace	
Magnesia	trace	trace	trace	trace	trace	
Alkalies	2.66	.30	1.62	1.22	0.13	12.66
Water	9.27	13.86	11.49	12.66	13.64	0.69
Total	99.40	100.13	100.75	100.42	100.07	101.06
Clay Substance	73.28	98.48	82.22	91.66	98.59	10.02
Feldspar	16.12	1.65	9.98	7.75	.82	74.82
Quartz	10.00	.....	8.55	1.01	.66	16.22
Total	99.40	100.13	100.75	100.42	100.07	101.06

The body mixtures worked out thus:

	A	B	C	D	E
Clay	87.20	63.55	77.74	69.01	63.34
Spar	7.91	25.57	16.60	19.84	26.20
Flint	4.97	10.91	5.70	10.12	10.12

These bodies were made up, when plastic, into small tiles and were glazed with different glazes. Two of these are shown on all of the five bodies, viz.:

Glaze No. 2:

$$\left.\begin{matrix}0.6\ PbO\\0.4\ CaO\end{matrix}\right\}0.2\ Al_2O_3.\ 2.4\ SiO_2$$

Glaze No. 13:

$$\left.\begin{matrix}0.300\ PbO\\0.344\ CaO\\0.206\ K_2O\\0.150\ ZnO\end{matrix}\right\}\ 0.250\ Al_2O_3\ \left\{\begin{matrix}2.68\ SiO_2\\0.32\ B_2O_3\end{matrix}\right.$$

It will be seen that in this series of bodies there is only one variable, the clay substance, and that this is variable only in the physical form. Thus all the changes observed in shrinkage and in co-efficient are due to this factor alone. It must be admitted, however, that the variation in physical form goes a little farther than the clay substance itself, for, while the flint and spar in the respective mixtures were finely ground, it is probable that the quartz and feldspar in the clays were finer still. The burn was at cone 8 and the following table gives the percentages of contraction and absorption:

	A	B	C	D	E
Contraction. Per cent.....	9.5	12.62	13.66	.....	11.3
Absorption. Per cent.....	2.19	3.5	0.13	10.6	5.55

The similarity of the coefficient of all the bodies is worthy of note and seems to show that clay-substance, whether derived from kaolin or ball clay, acts in much the same manner. The relative freedom of ball clays from crazing is probably due more to their high content of quartz than to any radical difference in the clay substance itself.

In continuance of this investigation portions of the five bodies were sectioned for microscopic examination. Comparatively little variation was observed, much less than would be expected from the appearance of the wares. When, however, the clays themselves are put under a high power the greatest difference is apparent. The kaolins are largely crystalline in character, the kaolinitic plates are distinctly visible and, in fact, form the bulk of the mass. In the ball clays, on the other hand, the clay-substance is so finely divided as to the colloidal in form. No structure whatever is discernible except an amorphous clot here and

there and the usual fragments of quartz, feldspar and mica.

It is evident then, that while clay-substance is identical in composition wherever it may be found, it varies widely in constitution and this influences body composition to a greater extent than has hitherto been supposed. We have long been accustomed to speak of vitrifying clays and have attributed their behavior to a high content of alkali. It is now seen that even when the alkali is adjusted to uniformity there remains a very great difference in the behavior of the clay.

The second question is: Is all of the alkali in clays due to the presence of undecomposed minerals such as orthoclase, albite, muscovite and the like? The presence of alkali in the soluble portion of a clay does not alter the fact that it came originally from these minerals, for it is evident that while under ordinary treatment they are not attacked by acids ,the drastic action of the rational analysis decomposes them all, at least partially. In other words, there is no reason for supposing that the alkali in soluble clay came from mica alone and that in the insoluble part, from feldspar, nor, even if this were the case, is there any reason for atttributing to each portion a different function. But if all the alkali be so derived it is easy to calculate the rational composition, for, given the amount of alkali in a clay, the feldspar will be found (presuming the alkali to be potash) by using the factor 1.085 for the alumina, and 3.828 for the silica. This gives as a rule very different results from those secured by the laboratory method, but the plan seems the more reasonable of the two having regard to the differences of opinion already quoted. One or two illustrations will elucidate this:

	Ultimate Analysis Per cent.	Insoluble. Per cent.		Lab. Result. Per cent.	Calculated Result. Per cent.
Silica	63.44	35.22	Clay sub.	63.96	59.79
Alumina .	25.95	.26	Quartz ...	34.30	28.77
Iron	.85	... .	Feldspar .	1.35	11.05
Lime ...	.28	.. ..			
Magnesia.	.35	. ...		99.61	99.61
Alkalies .	1.62	.17			
Water ...	7.12	.. ..			

The figures in the latter case are obviously the more reasonable, for the actual amount of feldspar denoted by 1.62 per cent. of alkali is 9.58 per cent. Iron, lime and magnesia should, however, by reason of their fluxing action, be added to the feldspar and this addition gives a total of 11.05. That the feldspar should be stated as only 1.35 simply because the bulk of the alkali proved soluble seems scarcely in accordance with common sense.

The same observation applies to a second example:

	Ultimate Analysis. Per cent.	Insoluble. Per cent.		Lab. Result. Per cent.	Calculated Result Per cent.
Silica	55.79	16.40	Clay sub.	83.22	71.65
Alumina .	30.59	.42	Quartz ...	14.92	7.90
Iron	1.09	....	Feldspar .	2.26	20.85
Magnesia.	.38	.. ..			
Alkalies .	3.28	.36			
Water ...	9.27	.. ..			

Here the feldspar denoted by 3.28 per cent. of alkali is 19.39 per cent. and the iron and magnesia bring the total to 20.85 per cent.

Occasionally, however, one finds a clay to which the calculation method will not apply, because there is not enough silica present to supply both the required amount of feldspar and the clay-substance demanded by the bal-

ance of the alumina, and this calls for further examination.

A German chemist has pointed out that certain salts in solution are adsorbed by clay-substance. They are locked with the kaolinite in such a manner that, while remaining uncombined, they cannot be washed out. Many salts will behave in this way, the amount adsorbed varying with different clays. It will not be necessary here to cover the whole field, inasmuch as the present investigation is concerned only with the alkalies, but a series of experiments lately carried out at Alfred University proves that potassium carbonate is adsorbed by every one of the clays in common use. The quantity taken up varies from .087 to .409 per cent. in accordance with the following table:

	Sol. Alk. Per cent.	Equivalent Feldspar Per cent.	Adsorbed Alk. Per cent.	Equivalent Feldspar Per cent.
1 N. C. Kaolin.....	.079	.467	.180	1.06
2 Delaware Kaolin ...	.094	.555	.120	70
3 Georgia Clay. . . .	.220	1.300	.087	.51
4 Eng. Kaolin.....	.201	1.180	.339	2.00
5 Tenn. Ball Clay.....	·058	.343	.409	2.43
6 Eng. No. 12 Clay ...	.150	.887	.290	1.71
7 Eng. Washed.....	.101	.597	.180	1.06
8 Mayfield Ball Clay.	.112	.662	.170	1.00

This, however, does not prove that clays already hold such alkali in adsorption, but so far no clay has been found which does not contain some. The alkali not being removable by water, dilute hydrochloric acid was used and in every case soluble alkali in small quantities has been found. The amounts are tabulated with the above for convenience. This fact is offered as a possible, if partial, solution of the phenomenon under consideration. The alkali is not all present as feldspar or mica, but is locked up in the clay-substance itself.

This may seem to supply a different answer to the

question from that at first suggested, but as a matter of fact, if the alkali retains its fusing property, and there is no reason to doubt that it does, it acts to all intents and purposes as though it belonged to feldspar and may therefore be considered as forming part of a similar mineral. If, then, a clay be found, for they are by no means common, in which the calculation fails, it is best to reckon the full amount of feldspar and to allow the remaining constituents to rank together as clay-substance. This will be found to be sufficiently accurate, especially as such clays are usually high in alumina, denoting the presence of bauxite or some similar mineral.

If, however, the facts relating to adsorbed alkali have any bearing upon each other and upon the case as a whole, it would be expected that a relationship would exist between the amount of free alkali contained and the amount adsorbed by that clay and such indeed is the case. The diagram shown will illustrate the fact that with but one exception the less free alkali a clay contains the more it will adsorb. This seems to confirm the idea that the free alkali found is actually retained by the clay in the manner suggested. The question of the origin of this alkali is an interesting one, though probably speculative. If the theory of the decomposition of feldspar and the solution of the alkalies as carbonates holds good, there would not seem to be any reason to doubt the possibility of these carbonates being retained by the newly formed clay.

In the light of what has been set forth there is forced upon the writer the conviction that the laboratory method of rational analysis is radically faulty. The assumptions upon which it is based are too large to be assimilated scientifically and the conclusion seems to be unavoidable that a simple method of calculation, as stated, is all that is necessary.

Acknowledgments are here made to the chemical department of Alfred University for help rendered in the analytical work and to Messrs. Randall, Shaw, Bell and

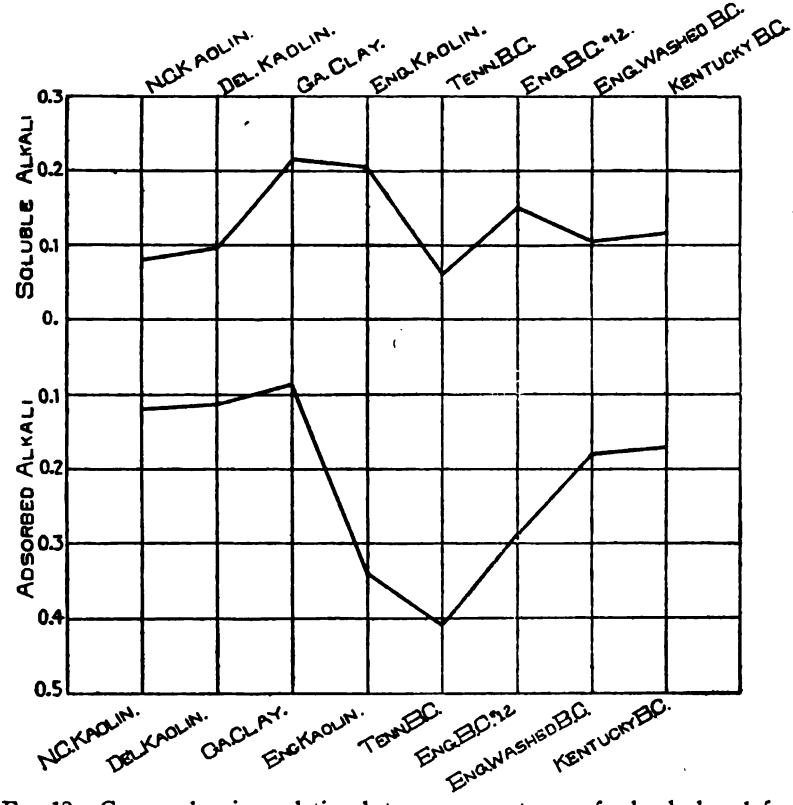


FIG. 18. Curves showing relation between percentages of adsorbed and free soluble alkali.

Podmore, students in the New York State School, for assistance in the experiments.

DISCUSSION.

Mr. Binns: I would like to ask Dr. Cushman whether, in his judgment, adsorption or absorption is the correct term?

Mr. Cushman: I think adsorption is correct in this sense. Absorbed, I think, means taken into the body; and adsorbed, on the surface.

Mr. Ashley: It seems to me this paper brings out the probable reason why the American manufacturer of earthenware does not care so much for aging his body, while the European manufacturer of porcelain finds it necessary. The European manufacturer has perhaps three or four times as much feldspar in his body, and in the aging process the changes which Dr. Cushman has explained take place. In the ordinary body here there is so much less feldspar that aging is of minor importance, there is so much less to be acted upon.

Mr .Stover: I will ask Professor Binns, in speaking of the calculated method, whether he means the one described in Jackson's book on Ceramic Calculations?

Mr. Binns: No; the only place you will find it, except in my own work, is in "Clays of Wisconsin." Jackson uses the laboratory method entirely, which he says candidly is radically wrong.

Mr. Stover: Is this method given in your paper?

Mr. Binns: Simply as to the two factors.

Mr. Stover: Would you object to giving it in the transactions so that anyone who wanted to do any work along that line could use it?

Mr. Binns: I did not give it because it seemed so obvious. I can give it if you like.

Mr. Burt: I think possibly there may be some difference in assuming, as Professor Binns does in his method, that the free alkali would carry a fluxing power equivalent to such alkali as was combined as feldspar. That is possibly an assumption which ought to be verified. I heartily agree that his results may be closer to what we actually get in practice, but I think further investigation might well be made as to the differences in fluxing power.

Mr. Binns: My point is that the amount of alkali is so small that the difference is inappreciable.

Mr. Parmelee: It is my recollection that that matter was discussed in a paper by Dr. Zimmer in Sprechsaal last summer, and I think he gave preference to the use of feld-

spar. Perhaps Mr. Ashley has a clearer recollection or that than I have.

Mr. Ashley: I have no recollection of it.

Mr. Cushman: Would it not be a question of the temperature to which you are burning? Because, if you rise to a high enough temperature, at which fusion is complete in the mass, all of the potash is active. If you do not get up to a certain temperature, there would be a difference between the potash in the orthoclase and that in the clay-substance.

Mr. Binns There is a difference on that ground. It is possible to produce vitrification considerably below the temperature at which some substances of the body fuse. We draw from as many different clays as possible the various alkalies they contain, and can produce vitrified bodies below cone two, three, and four. So the temperature is an important matter. At the same time it is less important than one would be led to believe, because the alkalies become operative, I think, at temperatures considerably lower than those at which the minerals themselves fuse.

Mr. Burt: That touches another pet hobby of mine. It takes up the question of the co-efficient of the clay-substances, whether obtained from ball clay or kaolin, an interesting point, I think, which has not been considered in the discussion. We have always been told by Seger that the ball clay has the higher coefficient. Taking that directly as Seger gives it in his rational analysis, we must assume that there was something in the clay-substance of the ball clay that carried the higher coefficient, whereas Professor Binns has shown by his method that this is really an error. Though the clay-substances vary, they show the same co-efficient. His trials bear this out admirably. The uniformity of the craze there, showing the uniformity of the co-efficient, is remarkable and proves the statement. So we are thrown back to consider just what is gained by ball clay substitution. I believe the gain comes from the fluxing power of the alkalies present in the ball clay as explained in my paper on coefficients.

THE COLORING POWER OF URANIUM OXIDE IN GLAZES OF VARIOUS COMPOSITION.

BY

FRANK HARWOOD RIDDLE, Columbus, Ohio.

On examining the literature on Ceramics in the library of the Ohio State University for matter concerning coloring oxides, it became evident that uranium has not received its share of attention. This may be due to the fact that it is an oxide difficult to use.

In a few brief experiments, the writer has endeavored to show its coloring power in glazes of various composition, and the extent to which these glazes can be loaded before becoming super-saturated. It has been the aim to use both a wide range in temperature and composition, in raw as well as fritted glazes.

Sources of Uranium.

Dr. Ries* gives the following sources: Uranite (UO_3, UO_2, PbO), etc. Gummite is of definite composition. The chief sources are mines in Central City in Montrose County, Colorado. It occurs chiefly as Gamotite. It is also found to some extent in Utah. Until recent years, most of it has been imported.

According to Prescott and Johnson** uranium has a specific gravity of 16.685. It melts at a bright red heat. Its chief ore is pitchblende, which contains 40% to 80% of U_3O_8. The metal burns to U_3O_8, with incandescence. It unites directly with chlorine, bromine, iodine and sulphur. Uranous oxide (UO_2) formed by the ignition of the higher oxide in contact with carbon or carbon monoxide is a brown powder soon turning yellow by the absorption of air.

Uranous hydroxide is formed by precipitation from

* Ries Economic Geology of the United States.

** Prescott and Johnson, Qualitative Chemical Analysis.

salt solution with alkalies. Uranic oxide (UO_3) is formed by heating uranic nitrate to 250° C. U_3O_8 is formed from UO_2 2 UO_3. Uranium acts as a base in two classes of salts, uranous and uranic.

About the only statement made by the treatises on Ceramics is, that uranium, under oxidizing conditions, gives an orange color in lead glazes and a lemon-yellow in alkaline glazes.

Cunynghame[1] says: "Yellow, so called sesquioxide of uranium, or what is really, uranate of soda, has a feeble coloring power. It mixes well with copper and chromium to give brilliant greens, and with gold a splendid orange. When mixed with powdered dense flint, and two per cent. of potash, it gives a bottle green, which gradually changes to a dirty yellow. A fine yellow can be obtained by using ordinary flint glass of the composition:

Flint	10 parts.
Potassium oxide	2 "
Lead	10–15 "
Alum	10–15 "

The series of experiments given below show results contrary to this statement, i. e,, orange can be obtained by using a lead glaze under oxidizing conditions, and in order to get a lemon yellow it is necessary to use a mixture low in lead, preferably with boracic acid present.

Alexander Brogniart[2] gives a method for the preparation of uranium oxide from the ore for use in ceramic work. It is too long to give here. Langenbeck[3] says: "Uranium is offered on the market as the oxide, ranging in color from a bright canary yellow to an orange yellow. The color varies with the glaze composition from greenish lemon to orange." How to get these various colors he does not state.

[1] The Art of Enamelling on Metals, p. 125.
[2] The Coloring and Decorating of Ceramic Ware.
[3] Chemistry of Pottery, p. 135.

Seger says that uranium is used for yellow underglaze colors, is sensitive to reducing conditions, and that the color is dissolved in the heat of the porcelain kiln.

Experiments Made.

The oxide of uranium used in these experiments is the standard "Yellow Oxide of Uranium" marketed by the late firm, J. Marsching & Co., of New York City. The composition, according to the Manual of the Ceramic Society, would be Na_2O, U_2O, $6H_6O$, and would have a molecular weight of 746. This would give 75.5% of pure $2UO_3$. The experiments below are given both as this and also figured as U_3O_8 with a molecular weight of 848.

The Glazes Used.

The trials were made up of pure glazes, and the uranium, figured as U_3O_8, was added in the following amounts: .003, .066, .01, .02, .05 equivalents. These calculated as Na_2O, U_2O_6, $6H_2O$, would be .0034, .0068, .0114, .0225, and .0570, which again would amount to .00256, .00513, .00856, .01712, .04280 parts of U_2O_6. The following table shows the complete chemical composition, composition of fritt, combining weight, etc.:

	Total Composition.	Fritt Composition.	Batch Weight of Fritt.			Batch Weight of Fritt.					Batch Weight of Glaze.							
			Combining Weight.	$NaNO_3$.	Whiting.	Zinc Oxide.	Clay.	Flint.	Borax.	Boracic Acid.	Fritt.	White Lead.	Whiting.	Zinc Oxide.	Spar.	Clay.	Flint.	Total.
A.	1.0 PbO } .2 Al_2O_3 { 2. SiO_2	Raw	.....	.....	.....	.....	.....	.....	.....	.....	.....	63 50	.....	.....	.....	12.71	23.66	99.98
B.	0.75 PbO 0.10 CaO 0.15 K_2O } .2 Al_2O_3 { 1.6 SiO_2	Raw	.....	.....	.....	.....	.....	.....	.....	.....	.....	57.85	2.97	.....	24.68	8.83	70.71	160.22
C.	0.50 PBO 0.15 K_2O 0.15 ZnO 0.20 CaO } .2 Al_2O_3 { 1.6 SiO_2	Raw	.....	.....	.....	.....	.....	.....	.....	.....	.....	43.98	6.81	4.18	28.45	4.39	12.26	99.99
D.	0.80 PbO 0.35 Na_2O 0.35 CaO } .35 Al_2O_3 { 2.5 SiO_2 0.5 B_2O_3	0.500 Na_2O 0.500 CaO } .215 Al_2O_3 { 2.5 SiO_2 0.713 B_2O_3	268.24	13.0	13.67	.....	15.17	34 06	.....	24.18	55.57	22.91	.....	.....	.....	15.27	6.21	99.78
E.	0.3 Na_2O 0.7 CaO } .5 Al_2O_3 { 4. SiO_2 1. B_2O_3	0.300 Na_2O 0.700 CaO } .4 Al_2O_3 { 3. SiO_2 1. B_2O_3	348.59	.....	14.91	.....	21.96	28.11	24.41	10.56	82.51	.....	.....	.....	.....	6.10	11.36	99.99
F.	0.4 Na_2O 0.4 CaO 0.2 ZnO } .25 Al_2O_3 { 2.5 SiO_2	0.444 Na_2O 0.444 CaO 0.111 ZnO } .1666 Al_2O_3 { 1.666 SiO_2	179.27	30.08	17.5	3.57	17.1	31.1	.....	.....	66.32	.....	.....	3.33	.....	10.6	19.73	99.99
G.	0.3 K_2O 0.7 CaO } .5 Al_2O_3 { 4. SiO_2	Raw	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	17.64	.....	42.12	13.0	22.22	99.98

Weight of uranium oxide added to 100 *gr. of dry glaze.*

	.003 equiv.	.006 equiv.	.01 equiv.	.02 equiv.	.05 equiv.
A	.677 gr.	1.354 gr.	2.257 gr.	4.514 gr.	11.286 gr.
B	.812 "	1.624 "	2.706 "	5.412 "	13.530 "
C	.913 "	1.826 "	3.043 "	6.087 "	15.217 "
D	.753 "	1.506 "	2.510 "	5.020 "	12.551 "
E	.602 "	1.204 "	2.006 "	4.013 "	10.033 "
F	1.046 "	2.092 "	3.486 "	6.993 "	17.433 "
G	.6412 "	1.282 "	2.137 "	4.274 "	10.685 "

Relation between U_3O_8, Na_2O, U_2O_6 $6H_2O$ *and* U_2O_6.

Equivalents, as U_3O_8.	As $Na_2O.U_2O_6$, 6 H_2O.	Contains U_2O_6.
.003	.0034	.0025
.006	.0068	.0051
.010	.0114	.0085
.020	.0225	.0171
.050	.0570	.0428

The above table shows what the different equivalents of U_3O_8 would be, expressed as Na_2O U_2O_6, $6H_2O$ when a definite weight of the material is used.

Mechanical Preparation.

All fritts were fused in Hessian crucibles in a small furnace until complete solution was obtained. While still in this molten state, they were poured in a thin stream into cold water to shatter the glassy mass as much as possible.

One kilogram of each glaze was weighed out, put into a 12″ ball mill and thoroughly ground for about three hours. All glazes were then passed through a 120 mesh sieve and evaporated to dryness. When perfectly dry, the charges were passed through a 20 mesh sieve to get rid of all lumps, and thoroughly mixed up to secure the best possible homogeneity. Then six one hundred gram samples

of each glaze were weighed out. To these samples, the proper amount of uranium was added as shown in the table.

The glazes were all weighed on torsion balances, sensible to .1 gram. The uranium was weighed on a more delicate balance, being sensible to .02 grams, so that there was very little chance for error. The uranium was previously ground and heated to 120° C. in order to dry it and then passed through a 120 mesh screen. After adding the uranium to the given 100 gr. samples of glazes, each was ground by hand in a mortar, screened through a 100 mesh sieve and applied to white, dry pressed porous biscuit tiles. Uranium, having a very high specific gravity, settles rapidly, so extra care was taken to have the glaze thoroughly mixed by dipping the brush well to the bottom.

The Firing.

Each series of glazes was fired in a separate sagger of the dimensions 8″ x 8″ x 1″. In each case the sagger was glazed with the same glaze that was on the trials (without the U_3O_8 added), so that no outside influence would effect the color, either by contaminating or weakening and drawing from it by volatilization.

The firing was done in an up-draft muffle test kiln, of 12″ x 10″ x 24″ inside muffile dimensions. It was later repeated in a 60″ x 24″ x 20″ down-draft kiln, all vacant spaces being filled up with brick checker work. A mixture of coal and coke was used as fuel in the proportions of about 2:1.

The temperatures reached were as follows:

Glazes A, B, C, were fired to cone 1.

Glazes D and E, were fired to cone 5.

Glaze F, was fired to cone 03.

Glaze G, was fired to cone 10.

The cone 10 fire was reduced, as the trials plainly show. Enough of the yellow is still visible to show definitely that it is a lemon yellow and not an orange.

Each burn was repeated at least twice and glazes A,

B, C and E were repeated three times, in order to get trials of as good a quality as possible.

Results.

The Coloring Power of Uranium.

Cunynghame, as stated above, says that the coloring power of uranium is feeble. When .006 equivalents will give as strong a color as the trials show, and .02 equivalents seem to be the limit and a decidedly strong color, his statement seems to be erroneous.

Effect of the Glaze Ingredients upon the Color.

1. The most noticeable fact is that the "lead glazes" high in uranium are a deep orange, while those free from or very low in lead are a lemon yellow.

2. The glazes highest in uranium are not only the richest, but also the strongest orange and take the most uranium into solution. A high lead glaze without the coloring oxide added is more yellow than a low lead glaze. But looking at the trials free from uranium, it is evident that the variation in shade is not as pronounced as the same glazes with the uranium added. This shows conclusively that the higher the glaze is in lead, the richer the orange color will be for a constant equivalent of uranium.

Composition of Glaze.	Color Effect of Uranium Additions. Equivalents of U_3O_8 added.					
	.008	0.006.	0.01.	0.02.	0.05.	
A. Cone 1.						
1.0 PbO 0.2 Al_2O_3 0.2 SiO_2.....	Pale orange yellow	Light orange yellow	Stronger orange yellow	Dark orange yellow	Orange brown	Raw glaze.
B. Cone 1.						
0.75 PbO, 0.10 CaO, 0.15 K_2O } 0.2 Al_2O_3 } 1.6 SiO_2..	Pale orange yellow	Light orange yellow	Stronger orange yellow	Dark orange yellow	Orange brown, segregation	Raw glaze.
C. Cone 1.						
0.5 PbO, 0.2 CaO, 0.15 ZnO, 0.15 K_2O } 0.20 Al_2O_3 } 1.6 SiO_2..	Light orange yellow, clearer color than above	Orange yellow, somewhat darker	Medium shade orange color	Orange brown	Dark brown, completely segregated, matt	Raw glaze.
D. Cone 5.						
0.30 PbO, 0.35 CaO, 0.35 Na_2O } 0.35 Al_2O_3 { 0.25 SiO_2. 0.50 B_2O_3	Pale lemon yellow	Light lemon yellow	Somewhat stronger lemon yellow	Dirty lemon yellow, somewhat reduced	Brown, reduced	Fritted.
E. Cone 5.						
0.7 CaO, 0.3 Na_2O } 0.50 Al_2O_3 { 4.00 SiO_2. 1.00 B_2O_3	Very pale lemon yellow	Pale lemon yellow	Good light lemon yellow	Lemon yellow, rather strong shade	Dark lemon yellow	Fritted.
F. Cone 5.						
0.40 Na_2O, 0.40 CaO, 0.20 ZnO } 0.25 Al_2O_3 } 2.5 SiO_2..	Pale straw yellow	Light straw yellow	Medium straw yellow	Strong straw yellow	Dark brown, reduced	Fritted.
G. Cone 10.						
0.70 CaO, 0.30 K_2O } 0.5 Al_2O_3 } 4.00 SiO_2.	Reduced	Reduced	.....	.....	.....	Raw glaze.

The fact that the glaze highest in lead is capable of taking the most uranium into solution is probably due to the fact that it fuses at a little lower temperature and, therefore, as the three raw lead glazes were in the same fire, the glaze which fused first had the longest time to exert its solvent action as a solution upon the uranium, consequently taking more of it into solution and combination.

3. What produces the lemon yellow?

(*a*) Absence of lead. This is easily seen by comparing the composition of the three deep orange colors with the lemons, i. e., A, B, and C vs. D, E, F and G.

(*b*) Is it the alkali or boracic acid that causes the lemon yellow? On close examination of D, E and F it is seen that D end E are more of a lemon than F, F having a very slight orange shade. The composition shows F to contain no boracic acid, while the other two which are more of a lemon yellow have some. Another fact is that trial D, which has 0.3 PbO, is not as much of an orange shade as F. D has boracic acid and F has not. These two facts seem to show that boracic acid causes the lemon color rather than the alkali. Trial G hardly needs considering in the series, as it did not receive the proper heat treatment. It is free from lead and boracic acid and shows a lemon rather than an orange shade. It does show, however, that uranium can stand as high a temperature as cone 10.

The different glazes become supersaturated as follows:

Trial A is very slightly supersaturated with .05 equivalent U_3O_8.

Trial B is good at .02, but very much supersaturated at .05 equiv.

Trial C slightly supersaturated with .02 equiv.

Trial D is good at .02 equiv., but supersaturated with .05.

Trial E, although blackened and the color destroyed

at .05 equiv., still retains its glazed surface and could hardly be called supersaturated.

Trial F is similar to E.

Trial G was not carried above .006 equiv., hence is undetermined.

In conclusion, the following statements may be made, based on the results of these experiments:

The presence of high lead gives rich orange shades.

The absence of high lead gives lemon shades, more especially when boracic acid is present. Also the higher the boracic acid, the more intense is the lemon color. The fritted glazes as a whole are capable of taking more raw uranium into solution than the raw glazes.

DISCUSSION.

Mr. Binns: I want to say right here: We are not, perhaps, in position to draw conclusions from work of this kind, but it emphasizes the value of experimental work. We want all members to bring here their experimental trials. They speak for themselves. We want to see the evidences of the work being done.

Mr. Walker: It is getting rather late to take time for remarks on a paper of this kind, but I do not feel I ought to let it pass without saying that my experience has verified some of the statements made by Mr. Riddle. A high lead glaze certainly produces the orange color with uranium. But, if I understand his paper, he claims the lemon color is produced by the effect of the boric acid.

Mr. Orton: No; he says it is produced by the absence of lead, but increased by the use of boric acid. He thinks it due to the fact that the boric acid gives better solution.

Mr. Walker: My experience is that a glaze high in lead, carrying as much as 0.5 equivalent of boric acid, produces a bright orange color. In fact, I would say that the boric acid has no effect, the color really being produced by the lead. But a glaze containing fully as much boric acid, with a high content of soda, produces the lemon color,

particularly when associated with lime. I do not believe the boric acid has any effect in the production of the color. That is my judgment, though I never made an investigation of any kind to prove it. I will be glad if Mr. Riddle will send me a synopsis of his paper, and I will, if possible, give you a little discussion on it.

WHAT SHOULD BE EMBRACED IN A GEOLOGICAL STUDY AND REPORT ON CLAYS?

BY

RICHARD R. HICE, Beaver, Pa.

In his retiring address at Birmingham, President Walker spoke of the work that could be done through the various geological surveys, and asked the question, "Is it not within our province to make friendly suggestions to the State geologists, in states having large clay deposits, asking reports that would be beneficial both to the state and to the consumer of clays?"

There has been considerable work done by some of the states and the published reports are of varying degrees of value to the clay worker. At this time there is a revival of interest in the study of geology in many states, and in most of these the investigation of the clay deposits is one study that will be, or has been, undertaken. The United State Geological Survey has also done some work along the line of clays, and other departments of the national government have made studies which are valuable, being along related lines. With all the work heretofore done, however, the question of its value arises, and whether, as proposed by Mr. Walker, suggestions as to the line and character of study, and of the report based on the same, would not be of value as indicating to the geologists the needs of the clay worker.

The character of geological work has undergone great changes within the last twenty-five years, and the results of geological explorations are now stated with a great degree of precision. In the early surveys of the various states the main work was of a technical character, little or no attention being paid to economic questions. While this is now changed, it must not be forgotten that the present ability to solve economic questions is the result of the threshing out of the truth from a mass of rival the-

ories, theories often in harmony when the facts found in the intervening territory were studied and analyzed. This changed condition is recognized by geologists themselves, as is shown by the following statement, quoted from the American Geologist: "It is not too much to say that to the miner, and hence to the mining industry, geology must look for most of its future progress, at least in the United States. In Canada the economic side of geology has always been put to the front, and systematic geology has been comparatively neglected, while the reverse has been the case in the United States. The example of New York State, which has entirely neglected officially, its economic resources, and has spent much on the technical and paleontologic aspects of geological science, has been followed by too many of the state surveys, and too closely by the United States Survey. Economic geology has made headway in spite of this indifference. Speculative and technical geology have had the field for many years, but it becomes more and more apparent that room must be made for an extension of that phase of the science which directly concerns the greatest number of people."

Since this was written, several years ago, conditions have greatly changed. Within the last two or three years, New York, in the reorganization of its survey, has made provision for economic work, not, however, excluding the technical side of the study. Canada seems to be giving more attention to the technical side of the study, for the mining interests involved in the Dominion require for their proper elucidation a mass of technical data, and the United States Survey, on the other hand, has undertaken, perhaps under pressure, a general line of economic work. All the present state surveys are more interested, than before, in the problem of how to make their work at once available.

I do not want to be understood as decrying technical geological work, for personally I am interested in it, and feel that there cannot be proper advances on the economic side of a geological question until the technical side has been studied, and I especially feel that the technical study

of clays, and of clay deposits and products, has been been, thus far, what is needed, indeed demanded, for the varied and ever-present industries which depend for their existence on clay.

This Society had at one time a Committee on Clay Testing, but the questions involved are not of a nature to be handled by a committee. Such a scheme of testing will require a properly equipped laboratory, and a vast amount of detailed work. It has been suggested that this Society endeavor to interest the United States Geological Survey in this laboratory work. It involves studies in chemistry, in physics and in mineralogy, for we all recognize that the behavior of clays depends not only on the chemical ingredients and combinations present, but also on the mineralogical form of such ingredients, and on the varying physical conditions of such minerals. Hence this study cannot well be the work of one man, but requires the combined skill and energy of a number of specialists. It cannot be expected that private enterprise can do such work, but it does seem a proper line of study for the United States Geological Survey, involving, as it does, not only the future of the ceramic industries, but deeply affecting every mining industry of the country. Should not this Society, as the one technical ceramic body in the United States, urge this study on the United States Survey, and indicate, at the same time, the questions involved in the determination of a uniform system of clay testing? This scheme of study would be the proper work of a committee.

I have diverted somewhat from the subject of state surveys, which will be the major portion, owing to the fact that if the work suggested were undertaken by the United States Survey, the question of what should be found in a state report would probably be greatly simplified. Turning to the subject of the state surveys, should reports of the clays of a state be prefaced with a treatise, more or less extended, on clays in general? Starting with a definition of clay and following with a discussion of the origin and properties of clays, their constituent elements, chemical

and mineralogical, their impurities, their plasticity and other physical properties, should such discussion be cut from the geological report, and have it restricted a statement of the different clays found in the various localities?

In discussing the various clay deposits found, shall the report give us the chemical, physical and mineralogical composition of each deposit, its mode of occurrence and formation, its present uses, and its possible ones as determined by laboratory experiments, together with the variations found in the various portions of each deposit?

If the possibilities of each deposit are to be determined, the geologist is confronted with the question before referred to, of what tests to use, and the amount of detail necessary, and shall he use the same methods in testing all clays, or all portions of the same clay? In other words he is confronted with the want of an accepted system of clay testing. Stated in another way, in the economic treatment of the subject, shall it be continued as a collection and arrangement of a mass of figures regarding what is now being done, and which is of little or no value to the ceramist, or shall it go further and indicate to the ceramist what additional uses may be made of each clay?

It is entirely feasible with our present technical knowledge to make a report, on coal for example, that is of great and immediate use. Take a bituminous vein, for example, and while it is perhaps practically horizontal, we can determine from the vein and adjacent strata the slopes and dips of the several parts, and therefore know where it can be opened and worked to the greatest advantage, and this is true whether the particular vein has an outcrop, or must be mined by shafting. The qualities of the coal can be determined, and whether it will justify mining for shipping purposes, whether it will coke or not, and if so whether it will carry the "burden" put on it by modern blast furnace practice. The methods possible to use in mining such a vein, depending on the character of the roof, and other geological questions, and lastly the amount, that is the

number of tons, that can probably be mined, under all conditions, from any portion of such vein can be approximately calculated, and with the information along these lines properly digested, mapped and described, the results of the study of that coal vein are at once available to all.

We know that some will say such studies should be made by those financially interested, but on the other hand private parties are not in position to make such surveys, nor could they do it at the comparatively slight cost that a connected survey could. Such work is being done in other lines of study, in the case of mineral deposits, for example, and in some of the oil and gas fields. Is it desirable that such work should be done on clays, and will the results justify the expense?

It is not the purpose of this note to suggest the proper lines of work to be pursued by a state, nor to indicate what have been the failures of reports already issued. But it is believed that suggestions by the members of this Society, and recommendations by the Society, would be kindly received by the heads of the various geological surveys, state and national, and would add to the value of reports when issued; and it is with the hope that such suggestions will be freely made, not only on the few points mentioned, but along the line of the whole subject, that this question has been suggested.

DISCUSSION.

Mr. Binns: I think we are all agreed as to the desirability of some such action as suggested. I think we are hardly competent, as a body assembled, without very close deliberative attention to take such action; and I suggest that the board of trustees consider the matter and suggest such action as it may deem wise. It should be carefully considered and a memorial prepared by the board of trustees and ratified by the Society at large.

Mr. Orton: I want to say this, that I have persistently objected to the reference to committees of any technical business which comes before the Society; but here is a

case which is strictly committee work. We cannot settle scientific facts by committee action, but we can set in motion machinery which will result in such achievement. The board of trustees has its hands pretty full with the business side of the society's affairs, and I do not think the trustees are just the ones to take up and consider this question. I think a special committee should be appointed to consider that and it would not be necessary, perhaps, for it to report back at this meeting. I know the Geological Survey of Iowa is now considering this clay question. I know that Professor Purdy, who has unfortunately been detained from this meeting, not only has been seriously considering, but is actually engaged on a clay survey of Illinois. I know Mr. Hice is seriously considering the same question affecting Pennsylvania. I myself have had to do with two clay surveys in Ohio and we are about starting a third. So there are men in the Society who are directly interested in the solution of this problem, and I think if it is referred to a committee, the committee can prescribe a course of work which this Society will probably be willing to endorse, and which, if we can secure the co-operation of the government and other states, may lead to splendid results. But I do not think the committee should be appointed with the idea of doing the work itself.

I do not want to take the time of the Society, but will say just a few words, as it is late. The situation as developed in Ohio is about as follows: We have been over the subject of clays twice, both times crudely, but the strictly geological part of it has been done better than the economic side, after all; so we can say that we know fairly well in Ohio where the clays are and what they are. In my judgment, it is more important, that the public should be enlightened as to how to use what they have, rather than to spend more money in researches into stratigraphical geology. The geologist is apt to view that side with enthusiasm. It seems to me the situation in most of the states is such as to demand a reversal of policy; and, while I think the purely geological phase of the work should re-

ceive due consideration, yet I do think geological surveys are going to become more and more bureaus for the dissemination of technical literature rather than scientific literature. When it comes to the geological aspect of it, geology is useful to find where the beds are, to classify them, judge from one locality where to look for another, and such matters as those. And there economic geology comes in and takes up the matter of useful application.

Mr. Binns: I fully concur in what Professor Orton has said, but I did not think the idea was that a plan of work was to be outlined. I simply thought we were to suggest that the United States Survey take up that work.

PHYSICAL TESTS OF IOWA LIMES.

BY

IRA A. WILLIAMS, Ames, Iowa.

Although lime has been used as a mortar since very early times and is of late being employed in various other ways in structural engineering work, few records of tests of those physical properties which make it of value are to be found. There are several factors that should be included in a complete investigation of the physical properties of limes. The influence of slaking with increasing amounts of water and the resulting change in volume; the increase in strength with increasing setting periods; and, since in practice limes are seldom used in the neat condition ,the effect of varying proportions of sand on the strength of the mortar and the rapidity of setting, are all lines of research which would doubtless afford information of much value to users of such cementing material.

There has also of late been considerable discussion as to the relative merits of the white or high calcium limes and the brown or magnesium limes. It is with a view to obtaining definite data on these several points that the following outlined series of experiments has been initiated. The work is being carried on under the auspices of the Iowa Geological Survey in co-operation with the Engineering Experiment Station of the Iowa State College.

Barrel samples of commercial lime were obtained from the principal producers in Iowa and a few from bordering states. While it was evident that the factors above enumerated were the important ones to be studied with each lime, considerable preliminary experimenting was necessary in order to be able to lay out an exact systematic method of procedure. The plan adopted in the beginning was as follows:

The quick lime was slaked with percentages of water ranging from the amount which would produce a dry pow-

der as a minimum, to a maximum of 300 per cent. by weight. Slakings were then made with 100, 150, 200, 250 and 300 per cent. of water, calculated on the basis of dry quick lime as 100 per cent. From each slaking, series of brickettes were made with the following sand dilutions,* by weight: one part sand to one of lime (dry), one and one-half of sand to one of lime, two of sand to one of lime, and so on to five parts of sand to one of lime. Four sets of brickettes were made from each sand mixture, to be broken at the end of four, eight, twelve and sixteen weeks respectively. Ten brickettes were used in each set from which to obtain an average.

Briefly, then, from the fat lime obtained by slaking in each of *six* different percentages of water, brickettes were made with *nine* different dilutions of sand. Since four periods of set were to be allowed, with ten brickettes to be broken at the expiration of each period, a little arithmetical juggling will show that for each lime tested according to this plan 2,160 brickettes would be made. As the work progressed, it was soon discovered that this general scheme required more or less modification according to the peculiarities of each individual lime.

Parallel to the physical tests, chemical determinations of the carbon dioxide taken up by the limes were made at each breaking. It was thought to in this way closely follow the progress of the setting and hardening processes.

The series of tests outlined are now but well under way so that few definite conclusions and no generalizations can as yet be offered. It is the object of this paper only to set forth some of the results obtained with a white, high calcium lime from Mason City, Iowa and to point out the few inferences it is possible to draw from them.

The Devonian limestone from which the Mason City lime is produced has the following analysis:

*A river sand was used, whose grains passed a standard 20 mesh (linear) sieve and remained on a 50 mesh sieve.

	Per cent.
Water	0.51
Insoluble	.63
Alumina and iron oxide	.71
Lime (CaO)	54.59
Carbon dioxide	42.89
Magnesia (MgO)	.47
Carbon dioxide	.52
	100.32

Analysis of the commercial product:

	Quick lime.	After slaking.
Insoluble	1.02	0.60
Alumina and iron oxide	2.98	2.80
Lime (CaO)	95.40	71.10
Magnesia (MgO)	.43	.40
Loss on ignition	0.00	25.60
	99.83	100.50

The table below gives in detail the breaking strengths of the brickettes. A Fairbanks standard testing machine was used.

Slaked in 75 Per Cent. of Water.

Time of set in weeks.	Ratio sand to lime.	Lbs. per sq. in. Average.	Maximum.	Minimum.	Ratio sand to lime.	Lbs. per sq. in. Average.	Maximum.	Minimum.	Ratio sand to lime.	Lbs. per sq. in. Average.	Maximum.	Minimum.
4	1:1	48.4	51.4	38.5	1½:1	45.7	50.5	39.5	2:1	54.5	64.4	46.1
8	.....	50.6	56.3	47.5	.....	40.7	44.5	35.	.....	54.3	63.3	48.
12	.....	56.1	60.4	45.	.....	47.1	50.	44.3	.....	48.5	52.5	46.
16	.....	53.9	50.	42.	.....	46.2	49.4	40.8	.....	52.	55.9	41.2
4	2½:1	55.1	60.4	50.4	3:1	50.6	56.2	41.9	3½:1	48.7	55.	30.
8	.....	54.6	58.6	51.	.....	52.6	58.4	44.5	.....	52.1	56.	46.5
12	.....	46.7	48.5	43.5	.....	48.1	51.	45.9	.....	48.	54.3	42.7
16	.....	52.3	56.9	49.5	.....	43.4	48.6	33.6	.....	32.9	53.	21.5
4	4:1	47.2	51.4	43.5	4½:1	48.7	53.	35.	5:1	43.6	58.4	33.
8	.....	47.8	57.	37.	.....	41.8	52.5	37.	.....	45.9	50.	34.3
12	.....	43.6	49.5	33.7	.....	42.6	46.6	38.4	.....	42.5	51.4	28.6
16	.....	41.5	49.	28.8	.....	44.6	50.	33.	.....	53.1	55.7	50.
4	5½:1	37.1	44.1	28.8	6:1	36.	39.6	34.6	.....	.....	.....	.....
8	.....	37.8	45.	32.6	.....	35.9	39.	31.	.....	.....	.....	.....
12	.....	38.5	44.1	33.3	.....	33.1	39.4	29.8	.....	.....	.....	.....
16	.....	38.6	40.8	34.9	.....	35.4	41.6	30.	.....	.....	.....	.....

Slaked in 100 *Per Cent. of Water.*

Time of set in weeks	Ratio sand to lime.	Lbs. per sq. in. Average.	Maximum.	Minimum.	Ratio sand to lime.	Lbs. per sq. in. Average.	Maximum.	Minimum.	Ratio sand to lime.	Lbs. per sq. in. Average.	Maximum.	Minimum.
4	1:1	47.3	56.2	39.7	1½:1	57.1	61.9	53.	2:1	55.9	73.6	45.4
8	.....	56.4	64.8	48.9	.....	60.5	68.7	48.5	.....	72.3	94.7	55.1
12	.....	64.9	76.7	52.5	.....	64.4	85.8	45.4	.....	76.2	89.8	54.1
16	.....	62.9	73.3	53.6	.....	73.2	91.6	55.6	.....	67.9	83.6	53.1
4	2½:1	54.9	62.5	43.8	3:1	49.9	65.6	40.9	3½1	51.	61.3	44.5
8	.....	64.6	80.4	53.5	.....	57.	67.6	51.5	.....	54.	62.8	49.4
12	.....	55.	67.7	41.	.....	54.6	63.6	45.0	.....	55.5	68.7	50.
16	.....	57.6	74.4	36.7	.....	53.1	58.1	40.6	.....	56.8	65.7	51.5
4	4:1	52.8	59.7	41.2	4½:1	47.6	55.4	38.8	5:1	64.1	75.4	52.5
8	.....	53.8	57.	50.	.....	49.6	53.	44.5	.....	68.1	74.5	65.
12	.....	52.2	58.7	45.4	.....	54.4	58.	48.5	.....	63.7	69.3	57.
16	.....	49.6	58.6	43.	.....	48.7	52.	43.	.....	65.8	72.5	59.
4	5½:1	56.4	64.7	52.	6:1	53.7	59.2	49.5	.....	.....	.....	.....
8	.....	56.7	62.	51.5	.....	52.5	54.5	50.5	.....	.....	.....	.....
12	.....	60.4	73.	53.4	.....	54.7	60.	49.	.....	.....	.....	.....
16	.....	50.4	50.4	41.	.....	47.8	55.	31.3	.....	.....	.....	.....

Slaked in 150 *Per Cent. of Water.*

4	1:1	41.	48.3	33.8	1½:1	47.1	49.9	36.1	2:1	45.	53.2	38.
8	.....	40.9	48.9	37.	.....	47.6	64.6	36.1	.....	46.9	56.7	40.4
12	.....	45.8	55.3	34.	.....	50.8	59.8	40.4	.....	52.1	68.3	39.
16	.....	47.6	55.7	39.2	.....	57.5	74.5	40.8	.....	62.	81.6	51.5
4	2½:1	55.4	68.7	38.8	3:1	60.7	68.7	45.7	3½:1	71.9	81.	61.8
8	.....	59.8	78.1	44.4	.....	54.	64.5	47.5	.....	60.7	71.4	41.4
12	.....	56.6	76.3	42.8	.....	63.7	72.1	51.	.....	76.2	84.1	69.7
16	.....	55.4	79.9	51.	.....	77.3	83.	66.3	.....	76.3	83.4	64.3
4	4:1	60.5	67.7	53.5	4½:1	51.7	59.4	44.9	5:1	46.	51.5	40.4
8	.....	63.9	74.5	50.4	.....	58.9	62.6	53.1	.....	47.5	51.	45.
12	.....	69.9	76.8	60.6	.....	61.1	64.3	49.2	.....	49.6	48.2	42.
16	.....	59.5	70.7	49.5	.....	60.5	68.4	53.1	.....	60.2	75.5	42.3

Slaked in 200 *Per Cent. of Water.*

4	1:1	45.	60.6	37.2	1½:1	44.4	58.3	35.7	2:1	45.2	54.6	38.5
8	.....	45.5	62.8	44.3	.....	51.	65.6	43.9	.....	57.3	69.7	45.9
12	.....	45.2	61.8	42.6	.....	40.	57.1	34.7	.....	50.6	61.2	40.
16	.....	47.4	53.1	41.2	.....	48.5	67.	36.4	.....	53.4	62.8	46.5
4	2½:1	41.7	55.2	33.4	3:1	46.9	57.1	37.0	3½:1	46.2	53.1	38.
8	.....	51.2	69.8	38.8	.....	55.	72.4	43.9	.....	56.	67.	46.5
12	.....	50.9	61.8	37.4	.....	49.6	65.9	42.3	.....	55.2	59.2	52.
16	.....	60.6	68.	53.1	.....	54.	58.2	48.4	.....	57.8	60.8	52.1
4	4:1	40.6	44.9	38.	4½:1	41.	44.1	38.6	5:1	43.8	46.0	39.8
8	.....	47.7	57.3	38.8	.....	53.2	63.1	38.8	.....	46.3	50.5	42.6
12	.....	52.9	60.	47.5	.....	52.2	57.4	45.5	.....	53.5	59.6	38.
16	.....	53.	57.	45.5	.....	54.9	57.1	53.	.....	52.7	54.5	47.

Slaked in 250 *Per Cent .of Water.*

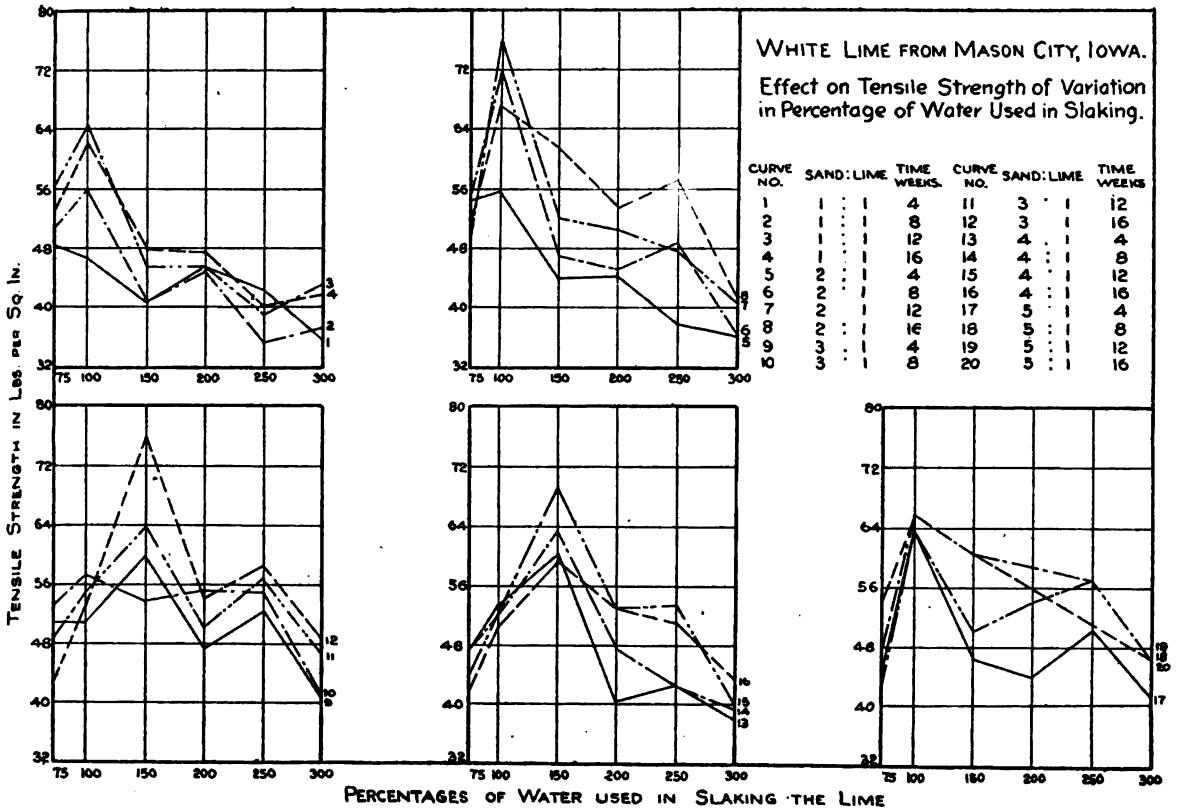
Time of set in weeks	Ratio sand to lime.	Lbs. per sq. in. Average.	Maximum.	Minimum.	Ratio sand to lime.	Lbs. per sq. in. Average.	Maximum.	Minimum.	Ratio sand to lime.	Lbs. per sq. in. Average.	Maximum.	Minimum.
4	1:1	35.4	37.6	33.2	1½:1	38.9	40.9	33.	2:1	37.9	41.	33.
8	.....	43.2	49.	36.	.....	45.4	53.2	35.4	.....	48.6	56.1	44.1
12	.....	38.	43.9	35.	.....	41.2	46.4	36.8	.....	47.4	55.5	42.8
16	.....	40.	45.2	36.	.....	43.9	50.	36.5	.....	51.8	58.9	42.
4	2½:1	42.7	62.5	38.8	3:1	52.6	61.	42.9	3½:1	52.7	60.	43.4
8	.....	50.1	60.2	36.5	.....	54.8	63.6	41.0	.....	48.5	55.1	40.4
12	.....	51.9	63.9	40.4	.....	56.8	70.6	45.2	.....	56.3	63.3	46.
16	.....	58.9	70.8	46.4	.....	58.7	69.	50.	.....	58.	62.	57.
4	4:1	43.2	64.	35.	4½:1	47.5	58.3	37.4	5:1	50.2	55.4	30.5
8	.....	43.4	48.	35.	.....	50.9	58.	35.9	.....	56.6	62.2	42.4
12	.....	53.	56.6	49.	.....	54.5	60.	45.5	.....	56.9	61.6	53.
16	.....	51.2	54.	42.	.....	.....	.....	.....	.....	.....	.....	.....

Slaked in 300 *Per Cent. of Water.*

4	1:1	38.1	47.4	25.5	1½:1	35.6	48.4	26.	2:1	36.	48.4	28.6
8	.....	35.8	54.2	27.3	.....	35.2	53.6	28.8	.....	†35.9	43.9	28.6
12	.....	43.	58.3	28.2	.....	38.5	54.6	27.8	.....	40.7	53.5	34.
16	.....	41.7	57.8	26.6	.....	40.8	51.	34.3	.....	41.2	52.1	32.
4	2½:1	41.8	50.	35.3	3:1	40.	50.5	32.6	3½:1	42.4	50.	33.3
8	.....	46.2	51.	40.8	.....	40.2	53.	30.6	.....	52.1	58.1	45.2
12	.....	51.1	60.2	39.6	.....	46.1	51.	36.	.....	52.5	55.	45.9
16	.....	56.8	63.8	50.	.....	47.8	54.	40.	.....	46.7	58.	35.
4	4:1	38.2	46.5	31.3	4½:1	39.7	43.5	32.8	5:1	40.7	47.5	35.
8	.....	39.2	51.5	31.9	.....	45.8	55.5	38.2	.....	48.3	54.9	42.7
12	.....	37.6	43.5	28.8	.....	43.6	48.5	35.9	.....	46.3	52.	43.
16	.....	43.	50.5	40.	.....	41.4	49.	30.7	.....	46.1	53.	30.
4	5½:1	37.8	44.5	34.	6:1	41.7	46.	36.6	.....	.....	.....	.....
8	.....	46.7	52.9	38.6	.....	46.5	51.3	41.5	.....	.....	.....	.....
12	.....	46.5	52.4	38.5	.....	47.7	54.3	4.31	.....	.....	.....	.....
16	.....	46.5	58.	43.2	.....	49.8	55.	44.8	.....	.....	.....	.....

From these figures, three sets of curves could be constructed which should bring out in a graphic way the general trend of the results. One set, with sand-lime ratio and average tensile strengths as co-ordinates; a second set, using the setting periods and tensile strength; and a third based on the percentage of water used in slaking and the tensile strengths.

Inspection of the table will show with reference to the



CURVE NO.	SAND : LIME	TIME WEEKS.	CURVE NO.	SAND : LIME	TIME WEEKS
1	1 : 1	4	11	3 : 1	12
2	1 : 1	8	12	3 : 1	16
3	1 : 1	12	13	4 : 1	4
4	1 : 1	16	14	4 : 1	8
5	2 : 1	4	15	4 : 1	12
6	2 : 1	8	16	4 : 1	16
7	2 : 1	12	17	5 : 1	4
8	2 : 1	16	18	5 : 1	8
9	3 : 1	4	19	5 : 1	12
10	3 : 1	8	20	5 : 1	16

FIG. 19. Tensile strength diagrams of Mason City lime.

first, that, in general the strength increases with increase of sand up to 3:1, 4:1 and even 5:1 in some cases and that beyond these ratios it decreases. Considered with reference to the effect of different periods of set on the strength, little more is to be observed than an increase in all instances during the first two months. With the longer periods the change is not sufficiently pronounced to afford a characteristic curve. It is evident that the lengths of time allowed for the lime to set were too short for the maximum strength to be attained. This conclusion is supported by chemical determinations of the carbon dioxide absorbed which show that carbonation is in no instance complete at the expiration of sixteen weeks. Sufficient time should be allowed for the longest period for all the lime to return to the carbonate condition. Then the curves constructed according to the first two methods mentioned above would indicate clearly the progress of the gain in strength according to percentage of sand and setting period.

The accompanying curves show the relation between the percentage of water used in slaking and the tensile strength of the brickettes. They are arranged in groups of four curves, each according to the whole-numbered sand-lime ratios. The general aspect of the five groups indicates a rapid rise in strength at 100 to 150 per cent. of water and as rapid a fall at 200 and the higher percentages. It is to be noted that 100 per cent. of water gives the highest strength with the 1:1, 2:1 and 5:1 sand dilutions, while with the two middle members of the series, 3:1 and 4:1, the highest strength is reached with 150 per cent. This may be but a coincidence, since results for only one lime are at hand. The increase in strength with successively longer periods of time can also be traced from these curves. It will be further noted that the rapidity of increase is greater the higher the percentage of sand used.

With data for but a single lime, general conclusions cannot be drawn and no attempt is made to do this. It

should be borne in mind that the results given refer to one lime and that the inferences may hold good for it only.

In planning further tests of several limes, the longest setting period has been lengthened to one year and sets of brickettes are to be broken at the end of 3, 6, 9 and 12 months. The percentages of water used for slaking are the even hundreds up to 300 per cent. as a maximum, besides the lowest percentage, which is to give a dry powder. Only the whole-numbered sand lime ratios are used in the later tests.

THE ACTION OF PHOSPHORIC ACID IN BODY MIXTURES.

BY

C. W. PARMELEE, New Brunswick, N. J.

The purpose of the investigation of which this paper is a record is two-fold: namely, first to learn what is the action of phosphoric acid in developing translucency, and second, its effect upon the fusibility of various common materials used in the preparation of bodies. Phosphoric acid as a raw material for the potter's use is had in the form of calcined bone, which is very nearly all tri-calcium phosphate. This material is used chiefly in the manufacture of bone-china. Members of the Society who were present at the Birmingham meeting, will remember Mr. Watts' interesting contribution to the literature on the subject, in which he gave probably the first recorded observations on its manufacture based upon scientific experimentation. Other observers have discussed the action of bone as a fluxing agent, notably, Messrs. W. Jackson and A. D. Holdcroft in the Transactions of the English Ceramic Society for 1904-05, but in so far as I have been able to learn, we have no precise statement regarding the function of the phosphoric acid.

The action of lime alone upon the physical properties of various mixtures we know in a general way. But the action of phosphoric acid, which constitutes nearly one-half of the calcined bone, we do not know except by inference. Of course we are at liberty to reason in this way, assuming we have two pieces of biscuit, each containing exactly the same amount of lime and other constituents, except in one we introduced the lime as calcined bone, in the other as whiting. In the first instance, the sample is highly translucent; in the second, it is quite opaque. Therefore we conclude that the phosphoric acid is the constitutent responsible for the translucency. Such reasoning is un-

safe and the conclusions are quite likely to be false. For example, to take a practical instance, all manufacturers of refractory ware know that quartz sand is very refractory. A great many consequently believe that a liberal use of it will tend to increase the refractoriness of their wares. As a matter of fact, the fusibility may be greatly increased.

In arranging my experiments, I wished to avoid the use of lime or any strong base, so I secured a quantity of aluminum phosphate of a commercial grade of purity, and used this as a means of introducing the phosphoric acid. The acid alone could not be used because of its fluid nature and ready solubility in water. The mixtures were made by thoroughly blending the materials, wet, in a ball mill, screening through 100 lawn and drying on plaster batts. An attempt was made to cast small test pieces similar to the shape of the evaporating dishes used in the chemical laboratory. This proved to be very difficult and unsatisfactory, so I was reduced to the necessity of cutting out thin circular briquettes. These were made as thin as possible in order to make it possible to compare their translucency. In addition, cones were prepared in a metal mold to serve for the tests for fusibility.

It is apparent upon casual inspection of the formula that owing to the use of the aluminum phosphate with a formula of Al_2O_3 P_2O_5, that after satisfying the required content of P_2O_5, there remained only a very small amount of Al_2O_3 to be introduced as clay, consequently, in order to secure as much bonding power as possible with the limited amount of clay, I used ball-clay in all cases, except the *A* series, which was made of 75 per cent. of china clay and 25 per cent. ball clay. These samples were fired between cones 9 and 10.

The various series prepared were as follows:

Series A.

A X	Al_2O_3	2.00 SiO_2		
A 1	"	1.88 "	0.056	P_2O_5
A 2	"	1.61 "	0.17	"
A 3	"	1.61 "	0.17	"
A 4	"	1.10 "	0.40	"
A 5	"	0.95 "	0.50	"
A 6	"	0.75 "	0.60	"
A 7	"	0.56 "	0.70	"

In this series we find a progressive increase in vitrification, improvement in color toward whiteness. A5 is very slightly translucent in strong light; A6 more so, but shows only a slight increase; A7 has well pronounced translucency.

The following series were based upon the type formula given by Mr. Watts, Trans. Am. Cer. Soc. VII, pt. 2, page 228:

$$\left.\begin{matrix} 0.2-0.4\ K_2O \\ 1.8-2.8\ CaO \end{matrix}\right\} Al_2O_3 \left\{\begin{matrix} 2.8-4\ SiO_2 \\ 0.6-0.933\ P_2O_5 \end{matrix}\right.$$

This was done in order to study the action under practical conditions in so far as the amount is concerned.

Series B.

B X	Al_2O_3	2.8 SiO_2		
B 1	"	"	0.6	P_2O_5
B 2	"	"	0.7	"
B 3	"	"	0.8	"
B 4	"	"	0.9	"

Here there may be observed an increasing whiteness, vitrification and translucency. No. 3 is cracked and No. 4 has numerous cracks.

Series C.

An increase in silica to 4.0 equivalents, otherwise like series B.

C X	Al_2O_3	4 SiO_2		
C 1	"	"	0.6	P_2O_5
C 2	"	"	0.7	"
C 3	"	"	0.8	"

Here also a progressive improvement in translucency and whiteness is observed.

Series D.

Introducing 0.2 potash, by feldspar, phosphoric acid and silica remaining the same as in series B.

D X	0.2 K_2O	Al_2O_3	2.8 SiO_2	
D 1	0.2 "	"	"	0.6 P_2O_5
D 2	0.3 "	"	"	0.7 "

DX has vitrified, but retains its original shape.

D1 has a white enameled appearance with edges rounded. Is translucent.

D2 similar to D 1, but drawn up more in the form of a button, translucent.

These have evidently increased in fusibility without marked increase in translucency over samples without the spar. It was found impossible to extend this series owing to the lean character of the mixture, which would have become more marked with increased spar content.

Series F.

Here the line is made the only variable.

F X	0.5 CaO	Al_2O_3	4 SiO_2	
F 1	0.5 "	"	"	0.6 P_2O_5
F 2	1.0 "	"	"	"
F 3	2.0 "	"	"	"
F 4	3.0 "	"	"	"
F 5	4.0 "	"	"	"

FX is a vitrified mixture of white color.

F1 is badly swollen to vesicular structure and dirty color.

F2, the same as F1.

F3 is an enamel-like briquette of good color and translucency.

F4 is quite similar to No. 3, but penetrated by cracks.

F5 has a greenish appearance, with rounded edges and rather stony appearance. It penetrated by cracks. Owing to the adhering sand, we cannot judge as to its translucency.

Series G.

Higher in phosphoric acid than series F. The amount of lime was varied.

G X	0.5 CaO	Al_2O_3	4 SiO_2	0.8 P_2O_5
G 1	1.0 "	"	"	"
G 2	2.0 "	"	"	"
G 3	3.0 "	"	"	"
G 4	4.0 "	"	"	"

G1. Badly swollen and vesicular. Dirty color.

G2. Swollen.

G3. Sample of normal shape, fine white color, very much like a good bone china, translucent.

G4. Similar to No. 3. Not quite so white and thickly penetrated by cracks, translucent.

G5. Similar to No. 3, translucent.

Series E.

Bone china mixtures.

$$\text{E 1,}\quad \left.\begin{matrix} 0.2\ K_2O \\ 1.8\ CaO \end{matrix}\right\}\ Al_2O_3\ \left\{\begin{matrix} 4\ SiO_2 \\ 0.6\ P_2O_5 \end{matrix}\right.$$

The phosphoric acid is introduced as aluminum phosphate.

E 2, same formula as E 1. Phosphoric acid introduced by bone.

Both similar in whiteness. E1 appears rougher and as though overfired. E2 has a good bone china appearance.

Comparative Fusibility.

The test for comparative fusibility of the mixture was carried out by setting one cone of each mixture in a fireclay base, the whole being placed in a sagger. We have two tests to report. The first fire was carried to cone 9 down, probably nearer to cone 10.

A series, all the mixtures remain standing.

B series, as series A.

C series, a sseries A.

D series, DX alone standing, Nos. 1 and 2 down.

E series, E1 swollen slightly, but standing, E2, down.

F series, FX standing, No. 1 melted, No. 2 melted, No. 3 tip down, No. 4 standing, No. 5 down.

G series, No. 1 melted to a swollen lump, No. 2 melted flat, No. 3 not quite flat down, No. 4 tip down, No. 5 standing.

The second fusibility test was carried to cone 13, flat.

A series Nos. 1, 2, 3, 4, 5, 6, 7 standing.

B series, BX standing, No. 1 tip bending, No. 2 half down, No. 3 tip standing, No. 4 one-half down.

C series, CX standing, No. 1 slightly bent, No. 2, one-half down.

D series, DX standing, No. 1 flat, No. 2 melted.

E series, both flat.

F series, FX standing Nos. 1, 2, 3, 4, 5 melted.

G series Nos. 1, 2, 3, 4, 5 melted.

Conclusions.

From these experiments we may conclude that the presence of phosphoric acid, if in sufficient amount, gives translucency, tends towards an improvement of the color, and acts as a flux and vitrifying agent.

With a slight increase in silica the fusibility is increased. These things it can do unaided. The presence of 0.2 potash does not affect the translucency, but increases the fusibility and causes the enamel-like appearance. Lime, if present in small quantities, increases the fusibility, but considerable amounts make the body refractory. It also gives the enamel-like appearance.

DISCUSSION.

Mr. Burt: I would like to ask Mr. Parmelee, in speaking of vitrification and translucency, whether they

did not go practically hand in hand, and whether he draws a distinction between the two? We are accustomed to speak of porcelain as translucent because vitrified, and to consider translucency as due to vitrification. I gather that he draws a distinction.

Mr. Parmelee: We might have vitrification at a certain heat, and firing a little higher increase the translucency. I think it is possible to have an increase in translucency subsequent to vitrification.

Mr. Cushman: In mineralogy we now distinguish three separate conditions, viz., crystalline, solid solution and emulsion. If a piece of glass, a vitrified substance, is ground up, it is not translucent, though it is vitrified just the same. I would say, that the difference between vitrification with translucency and a case where vitrification has taken place without translucency, might be just the difference, between a solid solution and an emulsion.

Mr. Stover: Wouldn't we have a case of vitrification and no translucency in a series of ball clays? You might call them parallel terms when you talk of bone china, but in speaking of a vitreous piece of ware, it may be of a stony nature; we may have vitrification irrespective of translucency.

Mr. Burt: At the same time, the translucency is due to vitrification.

Mr. Stover: You cannot speak of them as parallel terms. You are trying to say they are synonymous. I do not see how you can.

Mr. Burt: No; one is dependent on the other, I meant.

Mr. Binns: Mr, President, I think Mr. Parmelee is right in the contention that the two things are somewhat different, though we are in danger of branching off on a side issue. There are certain bodies which never become translucent, however, vitrified. Others vitrify first, and will be absolutely non-absorbent, but on continued heating some molecular rearrangement takes place which produces translucency in addition to vitrification. While it is true

that we cannot have translucency without vitrification, we can have vitrification without translucency.

The subject of the paper is "The Action of Phosphoric Acid in Body Mixtures," and I want to congratulate Mr. Parmelee on the way he has approached the subject. It is quite new to us that we have a distinct chemical action of phosphoric acid, independent of the base with which it is combined. We have formerly attributed the action of phosphoric acid to the action of the bone ash. I only wish we had some way to display the effect of these trials in the volume. I am delighted to have seen them and hope this is only the precursor of a great many interesting papers along this line from our friend from Rutgers. The little trials on the table will amply repay careful study.

A STANDARD FOR THE FINENESS OF GROUND MATERIALS.

BY

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Several investigators have been working upon portions of this subject for some years past both in America and in England and it is evidently regarded by potters as one vital to their interests. There is a general agreement that finely ground flint and spar produce a cleaner and more easily vitrified body, but no standard method has been suggested by which the degree of fineness can be gauged. The general opinion is that the use of a screen or lawn is only a check upon the passage of coarse particles and gives no clue to the size of those which are not retained. It is true that if it were possible to secure a series of lawns grading down to about 800 meshes to the inch, data would be secured which would throw a great deal of light upon the question. This, however, is not practicable and would be cumbersome to the last degree.

There is nothing more satisfactory for the purpose than some method of elutriation or washing. The principle involved is that a stream of water of a certain velocity will carry with it particles of a certain size. By subjecting a sample of a ground material, therefore, to streams of varying speed, the grains of successive sizes can be washed out, collected and weighed.

A method has also been recently devised by which the grains are settled by centrifugal force, but this, while very convenient and effective in a laboratory under careful supervision and in practiced hands, is scarcely simple enough for general use in the factory.

The best known apparatus for elutriation is that of Schoene, which consists of a glass funnel to contain the material, the stream of water being introduced from below. The pressure is measured in the outlet on a graduated

scale. Seger worked with this apparatus and selected certain velocities which have since become generally used. He found that a stream moving in a vertical direction at a speed of 0.18 mm. per second would carry off all particles smaller than 0.01 mm. in diameter. The next speed employed was one of 0.70 mm. per second and the third was at the rate of 1.5 mm. per second. This removed particles up to 0.04 mm. in diameter and everything coarser than this was left behind.

A great deal of work has been done with this apparatus, but it is open to several objections. It will occommodate only five grams of the material, and, consequently, the margin of error is large. It needs constant attention and, lastly, there is a great quantity of water standing around to be settled and the residue weighed before any result can be ascertained.

A piece of apparatus designed at Alfred removes all of these disadvantages. It probably has others, but in practical working it has proven itself highly satisfactory. This apparatus was used by Mr. Krehbiel in his work of 1904 and was illustrated in Vol. VI of the Transactions of this Society. He made no attempt, however, to discuss the apparatus itself or to advocate its use. The principle adopted is that of carrying a continuous stream of water from one vessel to another, the velocity being decreased by the increased diameter of each succeeding container. The vessels are copper cans of cylindrical shape, the bottom of each terminating in an inverted cone of 60°. Seger's velocities are adopted, but the order is reversed. That is, the highest speed is introduced first and those following decrease in order.

The first can is 5 cm. in diameter and 15 cm.high from the base of the cone. The stream of water is conducted from a container which is kept automatically at a constant level to secure uniform pressure. It is conveyed by a glass thistle tube to the bottom of the can and is so adjusted in volume as to rise at a speed of 1.5 mm. per second. This is checked by actual measurement. An overflow

conveys this stream to the bottom of the second can by means of another thistle tube, and were this second receptacle of the same diameter as the first the same speed of ascend would, of course, be maintained. It is enlarged, however, so as to afford an area in inverse proportion to the speed. The stream thus rises in the second vessel at the diminished rate of 0.7 mm. per second and, likewise, in the third at the rate of 0.18 mm. per second. The overflow from the last can passes down the waste pipe.

Its operation is very simple. Twenty grams of ground flint or spar are weighed into a small flask and thoroughly agitated with water. The slip is poured into the first or smallest can, the flask being washed out clean, and the three cans are filled with water. The stream is now started and, flowing at the required rate, everything below 0.04 mm. in diameter is swept out and through the overflow into the second can. Here, the stream, ascending more slowly because the can is wider, cannot support the larger particles so these fall back into the point of the cone. Everything of the diameter of 0.025 mm., and below is, however, carried into the third vessel where a similar separation goes forward. The stream ascends yet more slowly and washes up the finest of the grains, leaving only those of 0.01 mm., and larger, which are too heavy for it to support. The final stream bearing the milky washings of the very finest grains is allowed to run away.

The last feature of the apparatus constitutes at once its convenience and its weakness. By reason of the fact that the fine particles are not obtained and weighed there are no means of checking up results, but the weight of the smallest sizes is found by difference. Under some circumstances this would constitute a fatal objection, but in this case the error is less than it seems. Mr. Mayer, in his use of the Schoene apparatus, complained that a considerable proportion of the finer grains refused to settle and could not be filtered out, and everyone who has worked at any method of elutriation is aware that practically all the loss takes place in the fine particles which cannot be col-

lected. All that this apparatus does, then, is to recognize this loss and to make no attempt at securing the finest grains.

A strong argument for the general use of this apparatus is that it can be made in any tinshop if only the sizes of the cans are given and, further, it can be run entirely without attention except that the feed tank must be provided with an overflow which is kept running. The practice in the Alfred laboratory is to set the apparatus going early in the day and after some hours, or when the escaping water runs clear, to take out the thistle tubes and rinse them off each into its own can. The whole arrangement is then left undisturbed for two or three hours, preferably over night, when the clear water is siphoned or decanted off and the residues washed into beakers. After subsidence has taken place the water is decanted and replaced by distilled water. After another subsidence this is poured off and the residues evaporated. Distilled water is used simply to secure an easily removed residue. Ordinary water containing lime would cause the powders to become hard on drying, though it would not appreciably affect the weights. It thus becomes plain that any superintendent has here a ready means of ascertaining with ease, speed and sufficient accuracy the fineness of his ground materials. Moreover, if an agreement can be reached as to the most suitable commercial size as expressed by the surface factor, it becomes possible for potters to specify and for millers to offer standard flint and spar or materials of higher or lower fineness as may be desired.

That this method affords uniform results is shown by the following fact. Six students of the N. Y. State School were instructed to each take a sample of flint from the same can and to elutriate it. None of them had had any considerable practice in the use of the apparatus and yet the curves plotted from the figures they secured ran almost as one line, showing that reliable results are within easy reach. The respective sizes of the cans are 5 cm., giving a speed of 1.5 mm. per second; 7.32 cm., giving a speed of

0.7 mm. per second, and 14.58 cm., giving a speed of 0.18 mm. per second.

The desirability of presenting the fineness of material as a numerical value suggested to Mr. Jackson the calculation by which he evolved a surface factor. The weakness of this calculation has been pointed out by Mr. Purdy and it is not necessary to go over the ground again. Suffice it to say that the discrepancy shown in the figures of Mr. Jackson and Mr. Krehbiel, when the only change in the material was a rejection of the largest sized grains, caused great searchings of heart at Alfred and the matter was under consideration when Mr. Purdy's paper in part 3 of Vol. VII appeared. The contention in this seems so reasonable that something like a standard of agreement is now in sight. Using Mr. Purdy's factors certain work has been done with the apparatus here described and below are given some of the results:

Six Samples of French Flint Elutriated by Students.

Average size of Grain.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
0.0800 mm.	14.00	11.00	15.15	14.60	14.30	12.00
0.0325 mm.	20.30	21.75	21.30	19.20	20.65	23.60
0.0175 mm.	22.95	23.75	23.75	25.05	23.70	22.40
0.0050 mm.	42.75	43.50	39.80	41.15	41.35	42.00
Surface factor	1066	1086	1016	1043	1043	1055

In order to arrive at the facts of the usual run of commercial materials the following samples have been examined and the surface factors obtained are:

Feldspar.	Eureka Co., body spar	1028.
	" lawned 160	1047.
	" calcined	1198.
Feldspar.	Brandywine Co. No. IX	1140.
	" 2nd sample	1126.
	" glaze spar	1208.
	" No. 1 spar	891.

Feldspar.	Illinois Mineral Milling Co., normal	.....	1056.
Flint.	Eureka Co. French flint	.....	1031.
"	" lawned 160	.....	1111.
"	" reground	.....	1324.
"	American	.....	1078.
"	" lawned 160	.....	1073.
Flint.	Illinois M. M. Co., as used on the market	.....	1013.
"	" lawned 160	.....	1085.
"	" water floated	.....	1712.

These figures show that millers are already supplying flint and spar of about 1050 grade. Experience with fine wares has taught the writer that the re-ground flint at 1324 grade is none too fine and it now remains for the millers to show what they can do and to quote prices for different grades.

DISCUSSION.

Mr. Cushman: I think this question is a very important one. It is a matter which has been studied very little and the consequence is that we know very little about it. I think the subject is so important that I wish the Society would consider the appointment of a committee to report on the different methods which have been proposed and perhaps try to get some comparative results on different samples. We can take feldspar and by grinding in different mills and by one of these elutriation methods get very good relative results. As Professor Binns pointed out, these elutriation methods are open to criticism. If you take a finely ground spar and shake it up with water in a beaker and let it settle, in a short time a layer will form on the bottom, of settled material; but there will remain in suspension for a very long time material which does not settle.

That is a familiar fact to any one who has shaken up rock dust with water. A portion of it never settles. No one denies that the stuff which remains in suspension is extremely fine-ground; but the question I raise is, is it differentiated from a great deal of the material down at the bottom in a layer? I have considered that matter a good

deal, and I do not think it is different from the material at the bottom. Of course, there are coarser grains at the bottom, but so there is a great deal at the bottom that is just as fine as the matter in suspension. The elutriation method has not made the separation it has been given credit for. I admit there are coarser grains at the bottom, but I claim there are many finer grains at the bottom as well. The fine ones are not all in suspension.

This question of filtration of particles of very small magnitude presents some very interesting phenomena. If that which does not settle be shaken with pure water and a small amount of ammonium chloride be added, it will settle almost immediately, in a few minutes. In other words, a very small amount of soluble salts in the water will effect the settling of the particles in suspension.

That fact is made use of to-day, as everybody knows, in filtration methods in many river waters. We in Washington and the people of St. Louis know that water contains matter which will not settle, but it can be made to settle by a very small addition of soluble salts. They used to employ alum, and some processes now use it, but ammonium sulphate seems to be the material now applied for this purpose. The addition of a very small amount will settle water very quickly.

From the foregoing, it follows that the result to be attained by any elutriation method of this kind is going to depend to some extent on the purity of the water used, since the amount of soluble substances which will affect the filtration of particles is very small. It depends on how the water is distilled, how it is cared for afterwards, what kinds of vessels it has stood in. Distilled water which has stood in glass for even a very short time will contain decomposed of particles of the glass in solution.

It seems to me that the only rational way to approach this separation is by some sort of pneumatic separation, using air instead of water. For the reasons I have outlined, water is not a fair medium when it comes to the finest particles. It is all right for separating the coarse

from the fine, but when you want to differentiate between the very fine powders, it is not fair. The fact that water acts upon the surfaces of these fine particles and produces the surface condition there which changes the precipitation of those particles show it is not reliable in the handling of heterogenous powders. We find it is impossible to use a water method for sampling, sizing out the material for selective action, for the reason that certain minerals, those most easily decomposed by water, are floated out.

Mr. Binns: As I already stated, there is no scientific accuracy claimed for this process. The practical potter could not use a method of scientific accuracy. He has not the training. What I claim is that here we have an apparatus that he can put up and use; the flint-miller, if he likes, can use the same thing. Thus the potter can specify that he wants a certain size and can prove whether he is getting it. The separation of the grains in this little apparatus shows an almost absolutely correct separation of sizes. The differentiation of sizes is exceedingly small. I want to say further that if anyone would care to have determinations of his material made, I will be glad to do it and will make no charge whatever, unless the business should get too heavy.

Mr. Cushman: I did not mean to criticize the apparatus in the use it is recommended for. I was only carrying the discussion to the differentiation of the finer materia that runs to waste, about which we know little. I think it is the best method one could use for the purpose to which it is to be put, the sizing of coarser grains. But it would be interesting if a method could be evolved to separate out those very fine sizes.

DISCUSSION ON THE FINE GRINDING OF FLINT AND SPAR.

BY

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Several interesting articles have appeared in the Transactions which bear more or less upon the fine grinding of flint and spar.

Mr. Burt's paper in Vol III, page 17, treats of amorphous and crystalline flints from different sources and the effect they have upon the crazing of glazes, according to the fineness to which they are ground.

The next article is by Mr. Mayer, Vol. IV, page 25, discussing the effect of the fineness of flint and spar upon the fusibility of a whiteware body.

Mr. Binns, in his interesting article, Vol. V, page 281, concludes that the fineness of flint exerts more influence than the fineness of spar.

Mr. Krehbiel, Vol. VI, page 173, also concludes that the fine grinding of flint has much greater influence than the fine grinding of spar.

Mr. Mayer's paper deals with the question more definitely than any of the others. By a comparison of two bodies, one using English ground flint and spar, and in the other American ground flint and spar, Mr. Mayer proves the finer ground English materials are instrumental in very materially reducing the heat necessary to produce a body equal to the one using American material.

The article does not state what clays were used, but I presume they were American. Neither is mention made of the brands of spar and flint used, but it is to be assumed that the English ground materials were also English materials and the American ground materials, American materials. Upon this assumption I have been wondering whether there might not be a very decided chemical difference in the materials, in the state of the flint or

in the fusibility of the spars, which would exert a greater influence when used in a body, than the difference in the fineness of grain. There can be no question of the influence exerted by fineness of grain, but the above question is left in doubt, and if different brands of flint and spar were used, it would have made a more satisfactory and much more comparable test to have used the same flint and spar in all cases, but ground under different conditions.

Quoting from Mr. Mayer's article: "It has been to me, till recently, an unsolved enigma, why English potters can fire a dense body, with a clear ring and a close fracture at a temperature of Seger cone 5, whereas our body at a temperature of cone 8 down and 9 beginning to move, will not make so dense a ware or so close a fracture, while we have a body containing, as shown by chemical analysis, a percentage of alkali and fluxing material at least 35% greater than theirs."

While I do not question the greater advantage to be had from grinding the flint and spar as the English do in comparison with American ground materials, still with the excessive amount of fluxes in the American body over that in the English body, as given in the above quotation, it would seem that there certainly must be some factor entering other than simply the difference in physical condition of the flint and spar, assuming other conditions to be equal.

And here is the point I wish to make. In these articles and discussions no mention has been made of the physical characteristics of the clays used by the English potter.

While the writer's experience has been very foreign to anything like whiteware manufacture, it would seem to him that the physical character of the clays used in the manufacture of a whiteware body would exert as much or more influence upon the final density and hardness of that body as the physical condition of the flint and spar, if we consider their chemical activities as equivalent.

Some months ago, when looking over these articles,

this idea came to my mind and I determined to carry out a line of experiments for the purpose of verification.

In order to note the qualities of different American clays after burning by comparison with English ball clay some cones and shrinkage bars were made of English ball clays after burning by comparison with English ball clay, and Kentucky ball clay.

The results were found to be as follows:

Clay.	Color.	Hardness.	Burning shrinkage, in terms of dry length.	Porosity.
Eng. BC....	Gray	Vitrified, can not be cut, warped badly..	14.45%	None.
Tenn. B. C..	Strong cream ...	Can not be cut...	7.29%	8.03%
Fla. Kaolin.	Cream..	Barely cuts.....	7.33%	13.87%
Ky. B. C ...	Cream.....	Can not be cut...	6.95%	7.93%

The English ball clay shows much greater shrinkage than the American clays and no porosity as against very considerable values in all the others.

Mr. Zimmer, in his article, Vol. III, page 25, has plainly shown what great influence is exerted upon the maturing point of a body by a clay containing hydrated silicic acid and a look at the hard, warped, shrunken, vitreous, stoneware-gray English ball clay is sufficient to cause one to conclude that it would certainly exert a much more marked influence in a body than any of the phite porous American clays.

It was my intention to make up a series of bodies to further demonstrate the effect of different clays, but press of work has entirely crowded this out and this incomplete note is offered merely as a suggestion that the advantage of the English potter is due as much to the character of his clays as to the physical condition of his other materials.

THE USE OF BARIUM COMPOUNDS IN PREVENTING SCUM.

BY

ELLIS LOVEJOY, Columbus, Ohio.

Barium as a preventative of "scum" has been used many years, but there is so little literature on the subject that many do not understand its use, how it acts on the salts in the clay, why it frequently fails, especially beyond a ertain limit, and some doubt exists as to its efficacy. Theoretically barium is a perfect preventative of "scum," but in pratice it often fails.

The purpose of this paper is to call attention to lines of investigation which the writer belives would give valuable results in the use of barium to overcome efflorescence, nor are the lines suggested by any means a complete list.

Seger in his paper, "Concerning the Addition of Barium Compounds to Clay," says: "With a content of 0.1% of calcium sulphate in clay there will be required 0.127% of barium carbonate," or "0.170% of crystallized barium chloride." In the following paragraph, the solubilities of some of the salts involved in the question of scumming are given:

Calcium sulphate, $CaSO_4$, $2H_2O$, is soluble in 386 to 451 parts of water according to the temperature.

Ferrous sulphate, $FeSO_4$, $7H_2O$, is soluble in 1.64 to .27 parts of water.

Magnesium sulphate, $MgSO_4$, $7H_2O$, in 3.17 to 1.25 parts.

Potassium sulphate, K_2SO_4, in 10.31 to 3.82 parts.

Sodium sulphate, Na_2SO_4, $10H_2O$, in 4.34 to 0.32 parts.

In practice, we do not have to contend with any such quantities as these solubilities represent, except, perhaps, in the case of calcium sulphate. That the water which we use in our clay work may be fully saturated with calcium

sulphate when it enters the clay, or become so before leaving it in the dry-house, cannot be denied. Calcium sulphate is the chief source of our trouble, and we shall confine our discussion to it.

In passing, however, we wish to say that it would be valuable to determine what effect, if any, solutions of these other salts would have upon the solubility of calcium sulphate in concentrated solution, and upon its corrective, barium carbonate. It is possible that the soluble salts resulting from the reactions of these with barium carbonate may affect the solubility of the latter, and explain its sometimes erratic behavior in the prevention of "scum."

Efflorescences Classified.

There are three distinct lines of efflorescence, and we must confine this paper to one of them.

The efflorescence which appears on the material after it is laid in the wall is a problem in itself, and whether any conditions of chemical compounds to the clay can prevent it, students of chemistry must determine for us.

Kiln white, a much rarer phenomenon, concerning which we have little data, seems to be outside of any possible effect of chemicals in the clay.

Dry-house white, the common "scum," which appears on the material in the drying stage and continues unchanged through the burning, is usually calcium sulphate, and to it we will confine our attention.

Dry-House White.

If we assume that a dry pressed brick contains eight ounces of water, and that sixteen bricks can be made from one hundred pounds of clay, then we have in one hundred pounds of clay prepared for this process, 128 ounces of water.

This, since calcium sulphate is soluble, in round numbers, in 400 parts of water, will dissolve 128/400 ounces of calcium sulphate, or 0.32 ounces.

The equation for the precipitation of calcium sulphate by barium carbonate is as follows:

$$BaCO_3 + CaSO_4, 2H_2O = BaSO_4 + CaCO_3 + 2H_2O.$$

By weight, 172 parts of calcium sulphate require 197 parts of barium carbonate, or one part of calcium sulphate requires 1.15 parts of barium carbonate. The amount of 0.32 ounces of calcium sulphate, which may completely saturate the water in one hundred pounds of dry press clay, will require $0.32 \times 1.15 = 0.368$ ounce of barium carbonate to satisfy the requirement for complete decomposition of the calcium sulphate. Barium carbonate requires 14,137 parts of water for solution. One hundred and twenty-eight ounces of water will therefore take up 128/14137 ounces of barium carbonate, or 0.009 ounce. If 0.368 ounce of barium carbonate are required to precipitate 0.32 ounces of calcium sulphate, then 0.009 ounce of barium carbonate will precipitate 0.008 ounce of calcium sulphate. Thus, 0.008 ounce is 2½% of the amount of calcium sulphate which may be in solution in one hundred pounds of clay prepared for dry pressed bricks, and this is the initial value of a solution of barium carbonate.

The result of the initial decomposition is the formation of barium sulphate and calcium carbonate. Barium sulphate is soluble in 400,000 parts of water, and calcium carbonate in 28,000 parts, so that all the barium sulphate and practically all of the calcium carbonate formed, is precipitated. With this precipitation, more barium carbonate may pass into solution, followed by the reaction and precipitation until one or the other of the compounds is exhausted. Theoretically, therefore, we need only add enough barium carbonate to precipitate the salts which cause the "scum," and this seems to be the prevailing opinion in practice.

If we were dealing with these compounds suspended in water, we might expect the solution and reaction to continue to the end, but in a block of dry pressed clay, we have

very little circulation of the water, and cannot get the results which might be obtained from a free circulation. There is room for considerable divergence of opinion in regard to the possible value of an excess of barium carbonate in the water used in dry pressed bricks, but the writer holds that there is little value in any excess beyond the initial saturated solution, after, of course, the precipitation of any calcium sulphate in the water prior to its addition to the clay. The water, with barium carbonate in solution and suspension, upon being added to the clay is taken up hygroscopically by the particles of clay and becomes a part of the hygroscopic water already in the clay, and the barium precipitates there, having reacted with calcium sulphate up to the limit of the barium in solution.

The barium carbonate in suspension cannot follow the water into the particles of clay, and is left as a coating on their surface. The water is not a circulating medium. It is temporarily fixed in the clay particles, softening them and developing plasticity, and when the drying stage begins, it passes off to the surface, not, however, in all directions, as it entered, and in its passage taking up the barium carbonate deposited, but along certain lines ever towards the point drying fastest. That there will be some solution and precipitation during this stage must be admitted, but it will be quite limited. Whatever barium carbonate may line the channels through which the water is escaping, may pass into solution and accomplish its purpose, but the great bulk of the barium remains as a coating on the particles of clay.

The water during its stay in the particles of clay will take up the calcium sulphate in them to the point of saturation, so that we have a strong solution of calcium sulphate escaping from the clay to the surface of the mass with very little opportunity of bringing it in touch with sufficient barium carbonate to precipitate the sulphate. The conditions existing in a clay body are not favorable to the solution of such a difficultly soluble compound as

barium carbonate nor to the reactions which bring about the precipitation, but they are favorable to the solution of the calcium sulphate which finds its way to the surface without much loss in passage. A common practice is to add the barium in the powdered form, in the dry pan or other grinding machinery, and the little we may get in solution is quickly used up by the impurities in the water, or by the sulphates in the clay, more readily soluble than the calcium sulphate.

If the assumption that only the initial precipitation is effective can be maintained, then the addition of barium carbonate to the dry pressed ware is of no practical value. Our efforts should be directed towards increasing the initial precipitation by getting stronger solutions of the barium.

A stiff mud brick contains two pounds of water, more or less — four times as much as a dry pressed brick. This will dissolve 1.28 ounces of calcium sulphate in one hundred pounds of clay, which will require 1.47 ounces of barium carbonate to precipitate.

It will take up 0.036 ounce of barium carbonate, which in turn will precipitate 0.032 ounce of calcium sulphate.

The extremely low percentage, 0.02 per cent. of calcium sulphate which may be in solution in dry pressed ware explains why manufacturers of such products are less troubled with "scum" than the manufacturer of stiff mud ware. Moreover, the porous face of the dry pressed ware will tend to hide the deposits of calcium sulphate which may come to the surface in the drying stage. Increase the quantity of calcium sulphate four or five times, and deposit is on a dense face of ware, and we readily see why a compound which gives little trouble in the one process, becomes a serious problem in the other.

In one factory using both processes it was necessary to treat all the stiff mud products, but no barium was used in the dry press work. While "scumming" is of much

rarer occurrence in the latter, yet when it does occur it is much more difficult to overcome.

The writer's explanation of the ineffectiveness of barium carbonate in dry pressed work is based upon some observations in stiff mud work. In the manufacture of stiff mud bricks, we first ran the product quite soft, treating it, of course, with barium carbonate in the wet pan, and had very little trouble with "scum."

With the introduction of a repress, we made the bricks stiff enough to be repressed as they came from the separating belt, and they quickly assumed a leather hard condition, showing the absorption of the water by the particles of clay. These bricks came from the dry house and kilns badly coated with "scum." We doubled and quadrupled the quantity of barium without effect. We cut out portions of the clay which we thought made the trouble. We put in tanks in which the barium was stirred up with the water before being mixed with the clay, all to no purpose.

During this time roofing tile and hollow blocks made from the same clay were generally free from "scum," particularly the roofing tile but of course they were run much softer than the bricks, so much so, in fact, that the water could actually be squeezed out of the tile clots under the press.

As a possible explanation, it might be said, that in case the content of calcium sulphate in the clay was insufficient to saturate the water, the increase in the quantity of water would not increase the quantity of calcium sulphate, but would simply dilute the solution, while at the same time the barium carbonate would be increasing in quantity, maintaining its saturated condition from the barium carbonate in suspension. In the stiff mud we may not have had enough barium in solution to precipitate all of the calcium sulphate, while in the soft mud process the precipitation was complete. This argument reads better than it looks in figures.

Two pounds of water to each brick means 0.036 ounce of barium carbonate in solution in one hundred pounds of

clay, which will precipitate 0.032 ounce of calcium sulphate. This would be only 0.02%, a mere trace in commercial analysis. Such a minute quantity will not give any trouble by "scumming."

In the series from dry pressed products, through leather-hard stiff-mud, stiff-mud, soft-mud to slumming clay, we pass from hygroscopic water, through a mass saturated with water in which there would be more or less circulation of the water, to water with clay in suspension. In the latter extreme we would have perfect opportunity for the continued solution and precipitation until the barium carbonate or calcium sulphate was exhausted, but in just the degree that we decrease the circulation of the water, we reduce the efficiency of the barium carbonate, until in the dry pressed ware, and perhaps in the leather-hard stiff mud, the efficiency of the barium carbonate is limited to the initial solution, or 2.5 per cent. of the possible content of calcium sulphate in solution. We repeat, therefore, that our aim should be to increase the initial value of the barium solution.

Use of Barium Chloride.

The use of barium chloride, $BaCl_2$, $2H_2O$, which is soluble in 3 to 1.66 parts of water, is hardly to be recommended. While it will precipitate all the sulphur and thus remove all the soluble sulphates, yet any excess remains in solution and is drawn to the surface in the drying and there deposited to appear after the bricks are burned. Seger's advice not to use it in excess is to be heeded. Moreover, the resulting calcium chloride is also readily soluble and it, too, would find its way to the surface to affect the color. Its use would be safer in connection with barium carbonate. We could thus use less chloride than would be required for complete decomposition of the calcium sulphate, but yet enough of it to remove the bulk of the trouble, all of which would be used up in the initial reaction, together with any carbonate in solution, and for the decomposition of the remaining cal-

cium sulphate, we would have to rely upon the secondary reaction of the carbonate, which in dry press and leather hard, stiff clay would be of little value for reasons already pointed out, but even the little value thus obtained might remove the final trace of trouble. In any case we would have the soluble calcium chloride to contend with. It is very desirable that the problem be solved without the use of barium chloride.

Use of Acid Carbonate of Barium.

Fresenius says that barium carbonate is soluble in water containing free carbonic acid, forming the acid carbonate.

Other authorities confirm Fresenius' statement, and in one instance give the solubility as one part in eight hundred and thirty parts of water. To pass carbon dioxide through tanks containing barium carbonate in suspension would be a comparatively simple matter.

It is not within the province of this paper to go into the cost of producing the carbon dioxide gas, but we do not think the problem would be a difficult one nor the cost prohibitive. If the acid carbonate method with its more or less valuable by-products proved too expensive, we could fall back on the products of combustion of wood or oil, first using the heat value in some of our work, and then the chimney products in the above duty. The gas must be practically free from sulphur. The reaction of the acid carbonate with the calcium sulphate would be as follows:

$$BaH_2(CO_3)_2 + CaSO_4 = BaSO_4 + CaH_2(CO_3)_2.$$

If the acid barium carbonate has a solubility of 1 in 830, we have raised the initial value of the solution from 2.5% to 50%, which would eliminate the trouble from a great many clays.

We may have an excess of the acid barium carbonate in solution to give trouble, but its instability is a safeguard in this respect, and further, what has been said in

regard to using barium carbonate with barium chloride applies equally well to solutions of the carbonate and acid carbonate. The compound in solution is the acid carbonate and that in suspension the carbonate.

By keeping the former near to but below the quantity actually required, and relying upon the carbonate to decompose the remaining traces of calcium sulphate, we can have no trouble with any excess of barium solution.

The acid carbonate of calcium formed is a soluble salt, and like calcium chloride, remains in solution, but we are dealing with a compound a great deal more insoluble than calcium chloride, or even than calcium sulphate, and decrease the danger of efflorescence in proportion to the decrease in solubility.

The solubility of the acid carbonate of calcium is given as 1 in 1200. Furthermore, the acid carbonate of both barium and calcium can exist only in solution, and the chances are strongly in favor of their being unstable and passing back into the carbonate form and precipitating long before the drying process is complete.

An investigation of these acid carbonates is greatly to be desired.

Use of Barium Hydrate.

Burning barium carbonate with charcoal will reduce it to the oxide, which is quite soluble, according to one authority in 1.5 to 70 parts of water. The hydrate thus formed is soluble in 20 to 0 parts of water, being soluble in its own water of crystallization, at 75 degrees, nominally its melting point.

Barium carbonate does not readily give up its carbon dioxide, and it must not be inferred from the above bald statement that we can convert barium carbonate into barium oxide as readily and simply as we convert calcium and magnesium carbonate into "lime," but the simple process of mixing barium carbonate with charcoal and burning, especially under forced draft, will give a partial decomposition sufficient, at least, for our purpose.

The process would be crude and the stuff would have

to be freshly made, but if by its use we could introduce at once sufficient barium in solution to precipitate all of the sulphur and at the same time not leave dangerous by-products, we have solved the difficulty for any clay, and our trouble with "scum" would be over. The use of barium hydrate would result in the formation of calcium hydrate, and this in the burning would pass into the oxide. Calcium hydrate is soluble in 550 to 1,000 parts of water, and the oxide in 750 to 1,500 parts, in either case a decided gain over the solubility of calcium sulphate. Our greatest danger would be from any excess of the very soluble barium hydrate. If it can be kept below the point of excess, we would have little trouble with "scumming."

The tendency of both the barium and calcium hydrates to absorb carbonic acid from the atmosphere and pass into insoluble carbonates is in their favor. Add to this the tendency of calcium hydrate, and perhaps of barium hydrate, to combine with the silica of the clay, insures, in the opinion of the writer, freedom from any "scumming" because of their presence in the clay.

In conclusion the writer wishes to repeat the remark made in the beginning of the paper, that there is a valuable field for investigation in the use of barium. Many factories now making common bricks could put their product on the market for face work if the "scum" could be overcome, and factories making face bricks would reduce the loss from this cause. Nor is the trouble confined to brick manufacturers; it is only more apparent in their case. What effect the presence of "scum" may have on salt glazing and upon slip and enamel work is purely problematical.

In all this work the following caution must be observed: Barium in any soluble form is an active poison, and must be handled with care. The sulphate being insoluble has no effect except in so far as it may be made soluble by the digestive juices; the carbonate being difficultly soluble is safe to use; the chloride and hydrate being readily soluble should be respected and men who are

handling them should be careful to wash their hands before eating their lunches or handling their tobacco, or anything taken into the mouth. Naturally, the antidote would be some soluble sulphate.

DISCUSSION.

Mr. Layman: I had an experience which I think, may prove interesting in this connection. We are burning dry pressed brick from a clay charged with iron pyrites. The source of our clay is a vein covered, in one part of the property by a considerable depth of surface clay, and in another part by loose sand. In the part covered by clay, we experienced no trouble from the pyrites, but as soon as we struck the part of vein covered by sand, we got black heads on the brick, due to the soluble sulphate of iron, which occasioned a great deal of trouble. It may easily be seen that the portion of our clay which was covered by the sand oxydized readily and the pyrites contained in the clay was converted into sulphate of iron. The portion of our deposit with the overburden of clay had no chance to oxidize, hence the pyrites remained as such. Following the well-known principle for making soluble salts insoluble, we tried barium, which was not effective for the reason that it had to be added in such large quantities that the brick had a very disagreeable color. As every one knows, there are three insoluble sulphates, barium, calcium, and strontium sulphate. The last was ruled out by reason of cost, but the calcium compounds were available, so we tried the carbonate and found that it worked excellently well. I used of the carbonate, about 1 per cent. by weight and found that the scum was being overcome, and that we were making a better product.

THE TECHNOLOGY OF THE LIME INDUSTRY.

BY

S. V. PEPPEL, Columbus, Ohio.

There is no industry of equal commercial importance, which has made so little use of the technical knowledge of the chemist and engineer as have the lime manufacturers. Lime was probably one of the first products manufactured from rock material. We would, therefore, expect that an industry of such long standing would show the highest grade of technical development, but such, I am sorry to say, is not the case. The public demands, rather than the energy and progressiveness of the lime manufacturer, have made the industry one of great commercial importance.

Lime men, by ignoring technical considerations, have caused some large consumers, such as sugar and chemical manufacturers, who must have the highest type of lime of uniform character and composition, to put in their own plants. These latter manufacturers, in order to obtain a product as near perfect as possible, have had a little work done in the way of investigating the requirements for burning, in order to produce the most sensitive product, but practically nothing of this work has appeared in print in this country. Some work of this sort done in Europe, however, has been published and furnishes about the only reliable data which we have, and it is very meagre.

Information of a reliable character with reference to the problems of lime manufacture has seldom appeared in English and such as we have appears only in isolated chapters and simply reviews what has been published in other languages. Statements concerning lime which appear in books on other subjects are not at all concordant on many phases of the subject explained.

There has been some little work done on the uses of lime, mainly in connection with cement and published in connection with cement. These articles have appeared

in engineering journals. A few tests lacking explicit details have been published comparing strengths of mortars made from limes manufactured from dolomite and those manufactured from materials very high in calcium. Recently some few very good papers and some very interesting data has been published in the records of the proceedings of the National Lime Manufacturers' Association, but the information contained in these proceedings is available only to its membership. One valuable article has appeared in your own transactions, covering the substitution of hydrated lime for other calcium or magnesium compounds in glaze and body fluxes.

Within the last five or six years there has been a great awakening of energy among the lime producers which marked the beginning of a period of progressiveness on the part of lime manufacturers generally. There is a strong tendency to-day for improvement in plant and product. The lime men have finally realized that it is possible to introduce many economies in manufacture, but the average lime producer does not seem to know how to go about it. He does not seem able to grasp the fact that, if he does not possess the technical knowledge and skill necessary to accomplish these things, he should bring to his aid some one who already has this knowledge. As soon as he becomes accustomed to using the brains of others to assist his own, he will begin to make great strides in the way of improvement, and not before then can he hope to make great advancement, except by way of many costly experiments and quite a few unnecessary failures. The clay industry has just passed through the stage of development which the lime industry is at the present entering.

At a comparatively few plants in the United States chemical and engineering methods have been applied to their problems, and these plants stand at the head of the list in point of equality of product and economy of manufacture.

In going over the costs of manufacture in a large number of plants in some work done recently by the writer, the

fact was brought out that there is an extremely wide range between the fuel cost per ton at the various plants, when these costs were all figured to a unit basis of cost of fuel. It is very evident that here was an opportunity for the technologist or chemical engineer who is conversant with the lime industry, to introduce great economies in fuel at many plants, as well as to improve the product. With coal at -2.00 per ton delivered at the plant, it is costing to-day all the way from 50c. to 75c. for the fuel necessary to produce a ton of lime. There should be no such variation as this.

The inventor has been responsible for most of the improvements introduced in lime manufacture, although, as a rule, he had no technical knowledge to speak of, and good ideas failed of development simply because the owners of the patents lacked in engineering skill and technical knowledge. The patents on lime kilns have been very numerous, but we feel safe in saying that no inventor has become rich from any of them. The fact of the matter is that many of the patents after their expiration have furnished the basis upon which the improvements have been built by those with a broader knowledge of engineering. As a result each man is building his kiln according to his own ideas and we have as wide a range in kiln construction as we have in fuel cost. These kilns, as a rule, have been built without any foundation or reasoning as to why this or that height, shape or size of kiln should produce economical results. Kiln temperatures are not measured. Kiln gases are not analyzed and consequently the air excess and the temperature at which the fuel gases leave the kiln are unknown, and very little if any use is being made of the heat obtainable from the cooling lime. No methods of examination or control of the kilns are in use and the operation is entirely dependent on the skill of the burner. No methods of testing are in use to prove the quality of the product.

The greatest advance which has been made in lime manufacture has been the development of the hydrated lime industry. The lime producers are making and put-

ting upon the market a lime slaked to a dry powder. A number of different types of machines have been introduced for this purpose, and there was produced in the United States in 1905 about 250,000 tons of hydrated lime, yet during the development of this important phase of the industry very little chemical or technical work was done. Practically every thing was accomplished by the cut and try process. The various manufacturers of hydrated lime will tell you that their product is completely hydrated, yet the writer found on the examination of five different samples of hydrated dolomite lime a very wide variation in the water content of the products from different factories. If the producer of hydrated lime wishes to enter the more exacting markets, he must be able to deliver a product of a known and a uniform composition. The clay manufacturer could not use these limes unless he had their analyses or determined the composition of each shipment for himself.

The last few years has seen the introduction of a number of methods of firing, among which has been the introduction of steam. This also was done on the "cut and try" plan. The steam was introduced at first beneath the grate bars for the purpose of keeping the fire open and carrying the flame farther into the kiln without knowing that many years ago a German investigator had shown that the temperature to which it was necessary to raise calcium carbonate in order to completely eliminate the carbon dioxide was materially lowered by heating it in the presence of steam. If such were not the case, steam would be a disadvantage rather than an advantage, especially if the kiln gases left the kiln at a temperature of or in excess of 100° C. It is probable in the light of results being obtained at some plants that the intelligent use of steam in the furnace, either under or over the fire, will be the means of introducing some slight economy, if the kilns are of sufficient height.

Le Chatelier has shown that calcium carbonate completely decomposes at temperatures which increase with

the increase of gaseous pressure. That is, limestone burned in a partial vacuum is completely decomposed at lower temperatures than those when the burning takes place at atmospheric pressure or pressures greater than that. This fact has been almost entirely ignored since the majority, when using mechanical draft, have aimed to force the fire from below, rather than to reduce the stack pressure by induced draft.

Herzfeld found in experimenting with sixty-four different limestones that while lower temperatures would eliminate some of the carbon dioxide, a temperature somewhere near that of 1040° C. was necessary for complete decomposition. Some of the limes examined required this temperature, while others did not require quite so high a heat. Work done by the writer for the Ohio Geological Survey showed that the best burning temperature for lime was between 1000 and 1100° C. This work also indicated clearly that limes burned at temperatures much beyond 1100° C. lost materially in their sensitiveness to hydration. Theodore Gerhard, by using fusible alloys imbedded within the limestone, concluded that the burning temperature shown by his kiln was about 1100° C.

In considering the work of investigators in the lime field, one must not overlook the most systematic work which has been done, the work of the various experiment stations which have made a very thorough study of the use of lime for agricultural purposes and have indicated where, when and how it should be used, and have given the evidence to show how they have arrived at these conclusions.

The technology of the lime industry is only just begun. The chemical engineer and the industrial chemist should be able to do a great deal for the lime producers by applying many of the principles which have been proved by other industries far in advance of lime manufacturer from a technical point of view. He can also advise as to improvements either in construction or method of operation by measuring the kiln temperatures, the temperature of

the kiln gases and by analyzing the kiln gases, determine the air excess needed for complete combustion and so regulate the method of operation as to get the best possible value out of the fuel. Further, he can determine what fuels will give the best results in lime burning per unit of money expended, and, by getting the kilns under better control, can reduce the amount of core and overburned lime produced.

This paper was prepared mainly with a view of calling the attention of this body of investigators to the almost untouched field of research offered by the problems involved in the manufacture of lime and in its proper uses. The experimental work involved in the solution of many of these problems is not of the complicated and difficult type, all that is needed is systematic experimental work with close observation of attendant circumstances and a careful record of results obtained. In order that all data be made comparable and any sources of error picked out in the light of future work, a record of minute details of how the work was done and of all observations, even though they may seem unimportant at the time, should be made and reported with the results.

In the hope that some of you will lend your aid in building a foundation for lime technology, I will give a few of the more important unanswered questions:

What is the heat of dissociation of dolomite?

Are magnesian limestones of an intermediate composition between that of dolomite and calcite, made up of mixtures of dolomite and calcite, or are some of them mixtures of calcite and magnesite?

Does steam have the same influence on the burning of dolomite as on the burning of calcite?

What is air-slaked lime, chemically and physically? And how can its properties be accounted for in the light of its composition?

Where can air slaked lime be utilized?

What is the rate of air-slaking for different limes? Does the chemical composition alone fix the rate of air-

slaking, or has the physical character of the limestone before burning something to do with it?

Does the different physical character of the various limestones produce limes of different quality when the composition is the same? If so, why?

What type of lime, when used for mortar purposes, pound for pound, will develop in the mixtures the greatest tensile strength? Which the greatest crushing strength, in three months, one year, two years, and so on?

Is there a different reaction in the hardening of lime made from dolomite than in the hardening of limes made from calcite? If so, what is it?

Why are dolomite limes apparently more efficient in bolstering up the strength of Roman cement?

Why do dolomites hydrate so much slower than high calcium limes?

Is the weathering quality of mortars made from the two types of lime different?

Why does dolomite lime develop its strength more slowly than calcite lime?

The ultimate tensile strength of dolomite lime is apparently greater than that of calcite lime; why is this?

Why does dolomite lime show different working properties from that of calcite lime?

Why do dolomite limes, carrying the same amount of iron as an impurity, develop a greater degree of whiteness than a calcite lime with an equal or less amount of iron?

How can you completely hydrate dolomite lime on a commercial basis?

How do you explain the fact that some limes which are apparently completely slaked, and carrying mechanical moisture, will show further expansion when subject to steam at high pressure, when that same lime slaked in high pressure steam alone shows far less increase in volume than was obtained by slaking with water; yet this steam-slaked lime when mixed with sand and water and subjected to steam under pressure shows no further expansion?

How can the best and most uniform dry-slaked lime be most economically produced?

Why do calcite limes develop more strength in sand-lime products than dolomite limes do?

Where can the lime from calcite or dolomite, or their prepared hydrates, be used to replace more expensive reagents?

Where can the various limes or lime hydrates be safely used in the clay industry? And where will they be found unsatisfactory?

When using steam in the lime kiln, how much is necessary and advisable to use?

Does the introduction of steam in the lime kiln reduce the burning temperature sufficiently to compensate for the heat carried out of the stack by the water vapor?

When using mechanical draft, how much is gained over forced draft by the use of induced draft?

What size of stone will give the best results in kilns of different height?

What height of kiln is most desirable for natural draft? For induced draft?

Many more things that the lime manufacturer would like to know might be cited.

THE PREPARATION OF CLAY FOR DRY PRESS BRICK MANUFACTURING.

BY

ELLSWORTH OGDEN, Shawnee, Ohio.

The notes and data given in this paper refer to the plant of the Ohio Mining & Manufacturing Co., located in Perry County, Ohio. The product is a dry-press front brick in various colors, buff, gray, speckled and flashed.

A cursory description of the plant and the general method of manufacture will be given first, in order to acquaint the reader with the sequence of operations, after which some parts of the process will be taken up a little more in detail. An effort will be made to present the facts as they exist and the results that are actually obtained, without reference to points of weakness that would obviously admit of improvement.

The plant consists of 6 rectangular kilns of 100,000 capacity each and 9 round kilns of 70,000 capacity each, 4 four-mold presses and one two-mold press, with a daily capacity of 70,000 and an average daily output of 45,000. The grinding machinery consists of three nine-foot dry-pans, each of which is fed by a rock-crusher of the Blake type. Two of these pans are at the rear of the plant, as shown in the drawing, and their ground product is steamed and stored in bins, whence it is used at any one of three presses. The third pan, however, is temporarily placed up nearer the presses. The product of this pan is tempered with water in the pan and is used directly in one of the presses.

It will be observed that about three-fourths of our ground clay is steamed and put through the storage bins before going to the presses. It is this method of preparation that will receive most of our attention later.

Occurrence and Mining of the Clay.

The clay deposit lies 65 feet below the surface and is made accessible by a shaft with a double cage hoist. The deposit varies in thickness from 6 to 8 feet, and contains three distinct veins. The lowest of these is a hard, light colored, rock-like material, difficult to drill and apparently quite sandy in nature. Its average thickness is twelve inches. The middle vein is a soft, fine-grained fire clay, gray in color, with a beautifully pronounced conchoidal fracture. This is the heart of our material and ranges in thickness from 3 to 5 feet. It changes gradually toward the top to a darker and more rock-like material, which, though still buff burning, gives a darker color and is by no means as desirable as the lighter colored middle vein just described.

The practice is to load out the middle vein by itself for producing the lightest of the buffs and all of the gray brick. The remainder, the light colored sandy bottom and the dark colored rock-like top, are loaded together and worked up into yellow, buff and flashed brick. The mine is worked on a peculiar plan, which we shall term "the long-room and break-through system." By reason of an exceptionally good roof, this method is permissible, but would ordinarily be out of the question. Rooms 18 to 20 feet in width are driven parallel with center lines about 80 feet apart, leaving a 60 foot pillar between each two rooms. Break-throughs are then made at right angles to these long rooms in such a manner as to divide the mine into a cross-bar arrangement of rooms and square pillars. These break-throughs are on the average 18 feet wide and are spaced 70 feet, center to center. During 10 years of operation the working places have receded from the shaft until the most remote of these are now about 1,500 feet away. The average length of haul is about 1,000 feet. The clay is mined by contract. The working force consists of twenty-three clay diggers and three drivers; three horses are

taken into the mine every morning. This force delivers to the hoist an average of 160 tons per day.

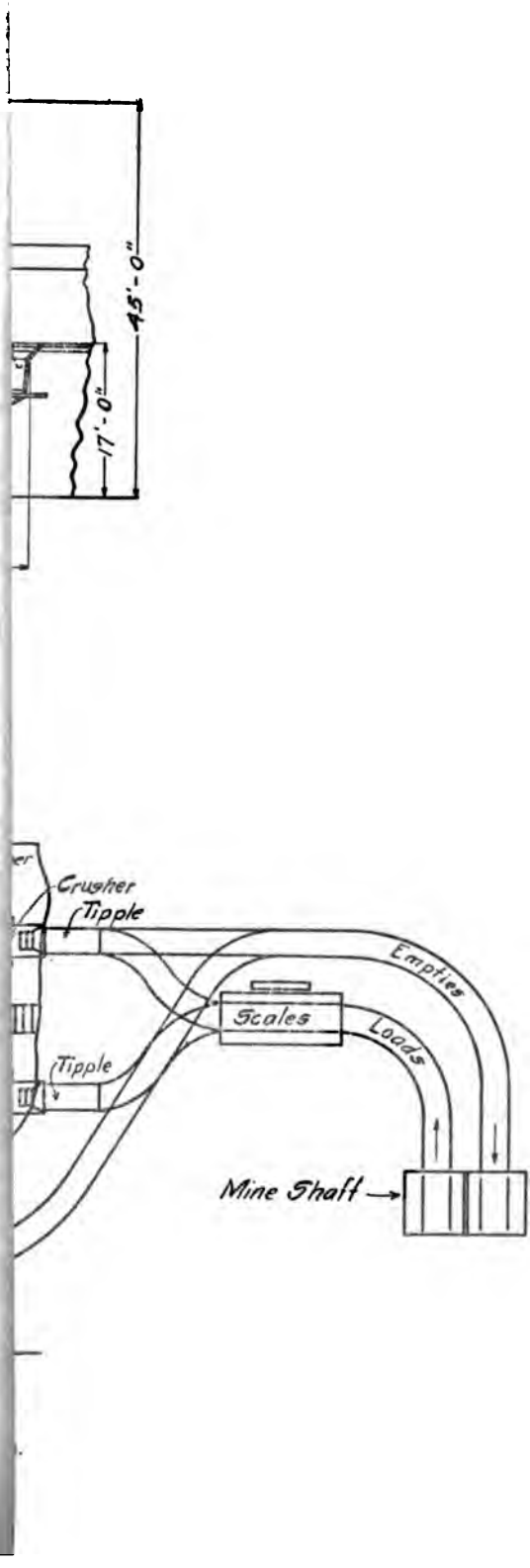
The following are actual figures for a portion of the year 1905, taken from our monthly records:

	Total net tons.	Days.	Tons per day.	Miners.	Tons per day per miner.
July	3697	23	161	23	7
August	4160	26	160	23	7
September	4206	25	168	23	7.3
November	3868	24	161	23	7

It will be observed that the average daily tonnage loaded per man is 7.07 tons, or four cars, averaging 3,600 pounds each.

Preparation of the Clay.

From the top of the shaft the clay cars are run over a scale and direct to the rock-crushers. These machines reduce the clay to a size easily handled by the pans. Passing direct from the crusher to the dry pan it is ground. From the pits beneath the pans, the clay is elevated and passes over inclined stationary screens. The tailings run back into the pan and the screened material is caught in a second elevator. This elevator raises it about 10 feet and discharges into a steamer. From the steamer the clay falls into bottom dump cars of 1,600 lbs. capacity each. The chute, A, discharging into these cars is so arranged that it can be made to fill a car on either side by tipping it first one way and then the other. When the cars are full of the ground and steamed material they are pushed forward over the particular bin to which the stock belongs, and dumped. The load from the first car falls into the bin in a cone-shaped pile, each addition to the pile enlarges


45'-0"
17'-0"
Crusher
Tipple
Tipple
Scales
Empties
Loads
Mine Shaft

the cone in all directions, causing a very complete distribution of the separate car-loads into layers, one above the other.

The clay is allowed to stand in the stock bins from 24 hours to 48 hours according to the supply on hand. This period of storing improves the working qualities of the clay. The Company has 10 bins, each one large enough to store clay for 22,000 bricks. This insures a good supply of prepared material on hand and gives considerable leeway between the grinding machinery and the presses. Either outfit may be temporarily stopped without stopping the other. Very often the pans are grinding an altogether different stock from what is being made into brick that day. The stored clay weighs 72 pounds per cu. ft. and slides at an angle of 39 degrees, when piled in the bins.

From the storage bins the clay is loaded into side-dump hopper cars of 1,800 lbs. capacity, run under the bins as shown at B. The clay is pulled down with an ordinary garden hoe. Care is taken to rake down the whole face of the pile from top to bottom, thus cutting across the cone-shaped layers referred to above and causing a further mixing of the ground product. The labor of loading the hopper cars is very slight indeed. These cars are run from under the bins onto a transfer car and carried forward on a transfer track to a point, C, about 12 feet to the rear of the presses; here they are dumped into the elevator boots, one elevator for each press, and the clay carried up and discharged into large tubs or rotary feeders directly over the presses.

We shall now take up the distribution of labor and the performance of the various parts of the clay preparing appliances. In the first place it requires a good man to run the hoist, he must be a licensed engineer, as our hoist is run by steam. He runs the loads onto the scales and weighs them and also cages the empty cars. Another man takes care of the two dry-pans. He could probably look after two more, if they were in line with the present ones. One man is stationed at each crusher. The mine cars have

one open end to facilitate dumping. They are run onto a small horn tipple directly above the crushers. The labor of feeding the crushers is not excessive, in fact it is regarded as one of the "snaps" around the plant.

The crusher jaw openings are 12 inches by 20 inches at the mouth, and 3½ inches by 20 inches at the bottom. The movable jaw nips 175 times per minute and has about 1⅛ inch play. The output of these crushers is limited by the capacity of the pans. Under these circumstances it requires 12 minutes to put through a car of 3,600 pounds. This would be a capacity of 72 tons in eight hours of actual crushing. As a matter of fact, however, the capacity of the crushers is fully three times this amount on this kind of material.

The average daily output of these two pans and crushers is 65 tons each, with an occasional day's run of as high as 80 tons.

The screens are of the inclined stationary type. Perforated metal plates are used. The slots are one inch by one-sixteenth inch. The screens are set at an angle of 38 degrees with the horizontal. Each screen consists of four plates, each four feet wide and three feet long, giving 48 sq. ft. of screening surface.

The steamers are very simple in construction. They consist of square stacks 20 inches on a side and extend through the roof of the building. As the clay falls through these stacks it passes through a zone of steaming. This zone is about 18 inches from top to bottom and is produced by two rings of small steam pipe extending around the inside of the stack and spaced about 12 inches apart. These pipes are drilled with 1/16 inch holes, so as to produce a great many small counter jets of steam which play upon the fine clay in its downward course. One man handles all of the product of the two pans from the steamer to the storage bins. He also finds time to keep the screens clean.

The handling of the stored clay from the bins to the presses requires two men and two boys. The boys hoe the loose clay down into the cars, keep the bins swept and put

the bottom boards in place; the two men transfer the clay cars and dump them into the elevator boots. With this equipment we run three presses with an average daily output of 13,000 brick each.

The tubs or rotary feeders above the presses are seven feet in diameter by three feet deep. There is a vertical shaft in the center of each tub, caused to rotate slowly by means of a beveled gearing, belt-driven from the line shaft. To this vertical shaft is attached a cross arm with short scrapers extending downward from it. The cross arm is so arranged that it slides up and down on the shaft according to the quantity of clay in the tub. As this cross arm revolves it sweeps the loose clay into the chute leading to the press. The primary purpose of these machines is to furnish a constant feed to the presses; they unquestionably accomplish some final mixing, but the latter point alone would not warrant their use at our plant, for the reason that the clay is well mixed by previous treatment.

It will be observed that we employ five men in handling the clay from the steamer to the presses. They supply three presses. If we had three dry-pans instead of two and used the clay direct from the pans to the presses it would then be necessary to increase our force by only one man to feed the third crusher, while we would do away with the services of the man who handles the clay from the steamer to the bins, and of the four men who now handle the clay from the bins to the presses. This would give a total of one hoist man, three crusher men and one pan tender, or a total of five men as against nine men now employed under the system of steaming and storing just described. But we would be to the extra expense of installation of a new pan and crusher and some conveying machinery, and the additional daily cost of power for operating these machines, none of which would be running up to their capacity.

There are, however, several other facts which justify the additional labor and expense bestowed upon our ground material.

The lee-way between the pans and the presses and the advantages of always having a supply of prepared clay on hand have already been mentioned, but the effect of this treatment on the clay itslf is an important one.

The apparent result of storing is a drying-out of the material because the stored product does not seem as moist to the feel as the freshly ground and steamed product. As a matter of fact, however, the moisture "soaks in," each particle clay becomes of like temper throughout the mass. This statement is borne out by the following moisture determinations on samples of steamed clay direct from the steamer, and on similar clay after twenty-four hours storing in the bins. The latter samples were obtained by stopping the press and taking clay from the moulds, just before pressure was applied.

Sample No.	Per cent. moisture.		
	Fresh steamed.	Stored 24 hours.	
1	6.99	7.48	The rock moisture was determined on clay fresh from the mine. The average of these samples was 4.1% rock moisture.
2	7.65	7.16	
3	8.92	6.52	
4	5.26	7.18	
5	...	6.76	
Range	3.66	1.26	

Experience at the plant has gone to show that the stored clay makes firmer and better green bricks than the freshly steamed material. When used direct from the steamer the clay does not work so well in the presses; it makes spongy bricks that have a tendency to crack under pressure and to crumble on handling.

That the stored material makes denser burned bricks, other things being equal, than the freshly steamed material, is borne out by the following statement. At one time it was the practice at this plant to use the clay direct from

the steamer. A steaming apparatus was placed directly above each press and the clay went to the presses steaming hot. Later, when the present system of storing clay was put in use, it was found that all the burnt bricks came out too large. It was necessary to reduce the width and depth of the molds by 1/16 of an inch, and the length by 1/8 of an inch. These green bricks were precisely the same size as those formerly made, but as will be clearly seen they contained more clay per cubic inch and consequently their shrinkage was less.

Another advantage with this process hinted at above, is the uniform shrinkage produced by reason of the fact that the moisture content is made practically uniform. Still another and very noticeable advantage of the stored clay is, that it will not stick to the sides of the chutes leading from the mixers to the presses, while freshly steamed material very often forms rings in these chutes and it requires severe pounding to dislodge them.

Another point in favor of the steaming process over that of tempering with water in the pan, is the very noticeably increased output of the pans and screens. This difference in capacity is caused by the fact, that when the clay is to be steamed very little water is added in the pan and the clay is considerably more dry during the grinding and screening than when the complete tempering is accomplished.

DISCUSSION.

Mr. Gates: There is one minor point which strikes me, in relation to this clay bin. This angle (referring to cone-shaped pile of clay in storage bin shown in drawing) varies somewhat, does it not, with the character of the mass?

Mr. Ogden: Very much.

Mr. Gates: I notice in our place, where we deliver the clay by screw conveyor, the tendency is for the fine clay to remain here on top, and the coarser particles to slide to one side. That results in the coarser clay being here, and the finer clay there (indicating), the fine clay being sepa-

rated to some extent from the coarser, the fine in the middle of the bin and the coarser in the bottom. Of course this difficulty is obviated to a greater extent by the mixer, but that is the result I have observed.

Mr. Ogden: I think that trouble would be increased as the clay is drier. In passing through the steamer the fine particles are caught and fastened to the larger particles, and so far as I have observed we have not suffered from that sort of separation.

The Chair: This paper is very intersting in two features, the steaming of the clay and crushing the clay before it comes to the pan. I think the idea of first breaking up the large lumps of clay before giving it to the pan is a very economical thing and ought to be practiced more than it is. It relieves the pan of a whole lot of pounding and breaking up which it ought not to have to do. If it is first passed through the crusher and the big lumps broken, you can feed it to the pan very fast. This not only increases the capacity of the pan very largely, but also its wearing qualities. The use of the crusher before you start to grind the clay is a very good feature, indeed. I would like to hear from some other dry pressed brick men on this steaming feature.

Mr. Lovejoy: There is no question about the value of steaming clay for dry pressed brick, particularly if a clay is of the hard character of a good many of our No. 2 fire clays. Originally we worked the clay from the crop, which was very soft and plastic, and we could handle it dry. Later, we drove under the hill where the clay was solid, then our clay was too hard, too granular. We finally put in a steamer and from that time the results were very superior. We found it worked much better, also, if after steaming the crushed clay was allowed to remain in the pile for twenty-four or more hours. As the boys used to say, "The cold clay worked better than the hot clay." I do not think any factory running on hard, solid clay can afford to do without steaming.

Mr. Burt: From what Mr. Ogden said, the steamer

consists of a wooden stack without any arms in there to mix the material, simply letting it drop through. Is that correct?

Mr. Ogden: I can answer that question better by a little sketch. (Makes drawing on board.) If you were standing at the top of the stack and looking down in it, you would see a line of pipe there (indicating) and one there, on both sides, the pipe being three-quarters inch in diameter. At the side of the steam zone there is a shaft, and three pipes go in each side like that (illustrating). The holes in those pipes are drilled so that the steam jets play like that (illustrating). The direction of these jets is an important feature. They are turned so high as to blow the clay away from the pipes and keep it from sticking.

Mr. Burt: Blowing down?

Mr. Ogden: Yes; blowing down and toward the center.

Mr. Binns: What is the pressure of the steam?

Mr. Ogden: We use boiler pressure, 100 pounds at the boiler, but probably not more than sixty pounds when delivered to the steamer.

Mr. Lovejoy: The form of steamer we finally adopted was a bottom dump, an inverted rectangular pyramidal bin with an iron door in the bottom and covered with a lid. The clay was run into this through a chute from the dry pan, and a steam jet was turned into the top of the box through the lid. The clay mass was in the shape of a cone, and the surface was brought into contact with this steam, and at intervals the whole pile was dumped, and the charge repeated. In that way it was exposed to the steam five or ten minutes.

ON THE CONTROL OF COMBUSTION AND ATMOSPHERIC CONDITIONS IN KILNS WITH INCLINED BAR FURNACES.

BY

W. A. HULL, Drummond, Pa.

At any stage in the burning of a kiln of clay ware, the burner's problem resolves itself into two factors:

I. To produce the proper rate of change of temperature in the ware.

II. To maintain in the gases surrounding, and in most cases penetrating the clay ware, the composition suited to the needs of the material at that stage.

Assume for the burner a knowledge of the conditions required by his unfinished product. His results then depend upon his ability to produce those conditions in the kiln he has to use with the coal that is available. It is with this phase of the burner's problem that we have to deal at present, but only in so far as it is applied in a single factory using one kind of kilns for the burning of practically one quality of clay and with no choice in coals.

The design of the factory in which the experience to be described was obtained was influenced by the designer's familiarity with the manufacture of sewer pipe in the vicinity of Akron, Ohio. The kilns were built round, 32′ in diameter with 18″ walls. A 9″ hob extended around the circumference to a height of 40″. Each kiln was provided with ten furnaces. These were of the type shown in figure 21. This style of furnace, provided with a good door for closing the charging hole, is in extensive and successful operation in factories using free burning, uncoking coals; but at the factory in question it was necessary to use a coking coal of the following composition:

Moisture	.62%
Ash	14.28%
Volatile combustible matters	33.98%
Fixed carbon	51.12%
Sulphur	3.14%

The content of ash and sulphur mark this coal as one likely to clinker badly. The natural consequence of this tendency, together with the coking quality of the coal, was that burners, accustomed to firing kilns of the same type, but utterly unfamiliar with coal of this nature, had difficulties which to them were insurmountable. After the first kiln had been tried the width of the furnace in the next ones built was increased to 24″. Still others were built later and in these the furnaces were made 26″ wide. After

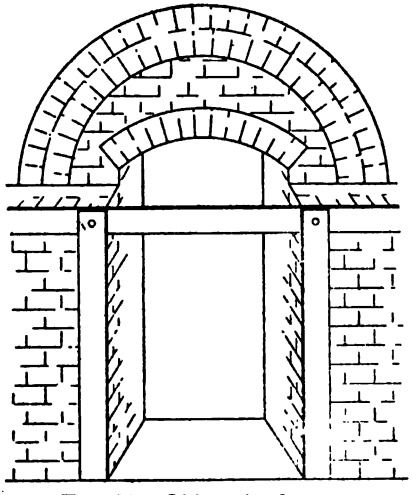


FIG. 21. Old style furnace.

a time the bars were shortened and supported at the bottom so as to permit of the removal of the ashes and clinkers under their ends. It was the practice to keep the charging hole of each furnace partially closed with a piece of sheet iron, which was set up in front of the opening after each firing.

When the writer took charge of this plant he found the furnaces in use as described and working fairly well. The ware matured at cone 3, and with proper handling there was ordinarily no difficulty experienced in carrying the burning along through the latter stages with no reduc-

tion. And reduction was a thing to be avoided. But proper handling was not an easy matter in firing this furnace with our coal. It was therefore considered best to alter the furnaces, converting them into the type shown in figures 22 and 23.

With this latter furnace the burners found the actual labor of firing considerably reduced and also experienced an abatement in the severity of the heat endured in clinkering. It was now easy to close the charging hole as

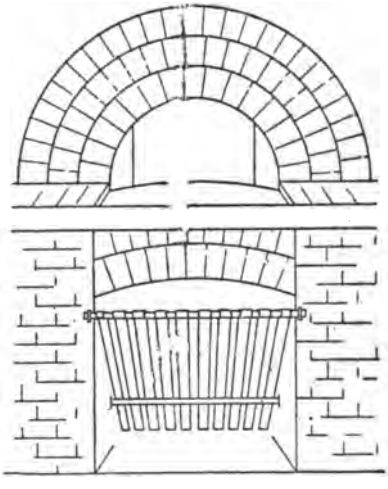


FIG. 22. First change in construction of furnace.

tightly as desired with the fuel itself, and the coking coal used would not fall away but would keep its place and serve the purpose of a door.

But with this furnace a new difficulty arose. The burners failed in many cases to finish the kilns with oxidizing conditions. It came to be considered necessary to exercise a good deal of skill in order to keep a kiln from "smoking." But inasmuch as some burns were good and others not so good, the writer attributed the poorer ones to carelessness, while the burners attributed them to luck. As none of the burns were bad enough to be alarming, no

other measures were considered necessary than to raise the standard of efficiency and reliability of the burning force.

After a time, the head burner reported insistently that certain kilns could be depended on to burn without "smoking," while others could not. The statement was absurd. But it was also reported that the kilns with the broadest furnaces, and therefore the largest grate area, were the ones that gave most trouble. This was not to be credited. Kilns smoked worse on some days than on others. Superstition was the only foundation for reports like these, for we always had reserve draught in check when kilns were on full fire. Instructions were given to give a "smoking" kiln more draught and to burn with fires as open as necessary to secure an air excess, thereby keeping the kiln gases oxidizing. The matter seemed too simple to be questioned. There was plenty of draught and plenty of grate area. In fact the kilns with the least grate area were the favorites.

Therefore the matter resolved itself in our minds into a decidedly easy proposition: To keep the lower portion of the bars covered with a layer of burning coke; to keep fresh coal coking on the upper portion; to push the entire mass downward on the bars when the fires needed replenising, thus continually charging roasted coals, relatively free from volatile matter, into the hottest portion of the furnace, while partially roasted coal from above was pushed downward replacing the coke. This left room at the top of the bars for fresh fuel. The method of firing avoided the charging of fresh coal onto a hot fire. On the contrary, it provided for its gradual roasting at the upper portion of the fuel bed on the bars. The layer of hot coke on the lower portion could be kept thin enough to admit excess air in that part of the furnace for the combustion of the fuel gases roasting out of the coking portion, and if this was not sufficient, air for the purpose could be admitted at will by open firing. With such an arrangement failure to maintain oxidizing conditions could result

from nothing else than bad judgment or lack of skill in firing.

All these things were impressed upon the burners without avail. Finally it became necessary to demonstrate them. But the demonstration was not an immediate success. It appeared that the burners were doing about as well as could be done. As they expressed it, "The fires burned out too fast underneath." That is, the coke in the lower portion of the furnace would burn rapidly and that portion would become thin and leave big holes through which too much air for good efficiency would rush into the kiln. To prevent this fault, the fuel bed would have to be settled before the last charges of coal had time to get the fuel gases roasted out of them. As a consequence, partially coked coal had to be pushed down into the hot zone where it would burn quickly, at the same time evolving combustible gases which would pour into the kiln only partially consumed. To thicken the bed of coals in the hot zone would relieve the situation by checking the draught through this portion of the fuel bed, thus causing the coke to burn out more slowly and give more time for the roasting of the coal on the upper portion of the bars. But to thicken the layer of coke, we must first produce the coke to do it with. Thickening it with gas-carrying fuel would defeat its own purpose. There remained but two methods to choose between:

1. To carry a low damper and hold back the entire burning operation, so as to give time for coking.

2. To produce the same result by leaving sufficient opening over the fuel bed to serve as an "air damper" to the furnace, thereby checking the rate at which the coals in the bottom of the furnace would burn out, and at the same time admitting air for the combustion of the gases evolved in the upper portion of the furnace.

The disadvantage of the former method is apparent. As for the latter, it was even more expensive. The explanation is not difficult when one considers the form of this furnace. Air admitted between the fuel-door and the

arch would enter the bag compartment cold. Moreover, it entered above the furnace proper, and rushed into the kiln without any adequate mixing with the uncombusted gases which were pouring in at the same time. The result was that oxidizing gases and reducing gases would enter the kiln at the same time from the same furnace. These gases would mix more or less perfectly in their course through the ware, giving a "long flame" through the kiln and into the stack, producing good flashing conditions but no reliable oxidation. In many cases trials drawn from different levels during the burning would indicate a reducing condition near the top of the kiln and no reduction near the bottom. Again a finished piece of ware from one level would show the effect of reduction, while a piece from a different portion of the same kiln would not. Broken pieces of ware frequently gave evidence that one side of the piece had been exposd to kiln conditions radically different from those effecting the other side of the same piece.

The surest way to maintain oxidizing conditions was to follow the apparently absurd course of carrying a low damper, thereby holding back the burning to give time for the coking. This explained a condition which had been baffling at the time of its occurrence. One kiln which had been behaving perfectly well with its flues badly choked, "smoked" persistently after being cleaned. The burners had failed to make allowance for the freer draught.

But the head burner's statement held good: "Some kilns could be depended on for conditions difficult to secure in others, and the ones that gave the best results were the ones with the narrowest furnaces." The explanation for this situation was discovered in the fact that the coking took place most rapidly near the sides of the furnace, the heat for the roasting being supplied to the mass of coal from the brick work of the furnace walls. The coking accomplished in this way amounted to as much in the narrow furnaces as in the wider ones, but the relative value would

be greater in the narrower furnaces, because the total quantity of coke required in a given time would be less.

These observations now brought to mind more vividly a suspicion that had been lurking there since the time when the burners placed sheet iron screens in front of the charging holes of the old furnace to serve as doors. These plates never fitted tightly against the furnace mouths, but merely leaned against them, forming a screen or barrier in front of the opening, and at the same time leaving a triangular gap on each side, averaging perhaps sixteen square inches or equivalent to a hole four inches square. The two gaps would equal a 4″ x 8″ hole over each fire, and this was considered an expensive luxury. As has been stated, these screens were considered both unnecessary and inconvenient and were discarded. But the discarding process was a slow one. The burners still found excuses for using them, off and on, for some time. This was attributed to their lack of skill in closing the furnace mouth with coal. One Italian burner, who was really good at getting results, was observed to use the sheet iron screens after they were supposed to be adorning the scrap heap. When told to throw them away he protested that without them he could not raise the heat without "smoking" the kiln. Such a statement did not seem reasonable at the time, but our later experiences demonstrated its soundness. The real function of these screens was not so much to prevent an unnecessary amount of air from entering the furnace as to convert the furnace mouth into a coking chamber. The opening could be closed as nearly tight as desired with the coal itself, but, given the protection of the screen and supplied with air admitted along its sides, the fresh coal in the mouth of the furnace would ignite. At the same time the heat reflected by the screen and from the brick arch above was sufficient to raise the air admitted to such a temperature that combustion of the fuel gases would take place in the furnace itself. Moreover, the condition tended to perpetuate itself. The heat generated by the combustion kept up the temperature of the air, and by

roasting the gases out of the coal stimulated more combustion and hastened further roasting. By the time that it would be necessary to settle and replenish the fire in any furnace, the last charge of coal would be relatively free from volatile fuel. The remaining gases would be consumed by the excess air admitted around the edges of the screen; for with this arrangement the air would be raised over the ignition point of hydro-harbons, which is somewhat higher than 650° Centigrade, before it passed into the kiln.

While these "post mortems" were under consideration, it was deemed wise to have some improvement plans crystallizing. We knew we must have furnaces in which we could easily burn our coal in such a way as to raise our kiln temperatures rapidly when we wished, and at the same time give constantly oxidizing conditions. For the sake of economy we wished to alter the old furnace as little as possible, but our experience had driven home the lesson that with our conditions we must provide for two things:

1. Greater coking capacity in proportion to the consumption of coke.

2. The heating of the air admitted to the furnaces and its mixture with the gases roasted out of the coal before these gases could pass out of the furnace and into the kiln chamber.

The first requirement called for a coking chamber with a good ample coking plate. Such a furnace is not difficult to design in connection with an unbuilt kiln, but to design one that would be fitted into our old kilns satisfactorily and at the same time economically was not so simple a matter. To secure the second condition a down draught furnace was to be recommended. The same difficulty confronted us as with the coking plate. And, even a down draught furnace has its drawbacks. The best compromise seemed to be a simple modification of our inclined grate furnaces, see fig. 23. By constructing a set of arches over the upper portion of the fuel bed, sloping downward in the shape of a roof roughly parallel to the grate bars and

high enough above them to leave room for the bed of fuel, we got the effect of a down draft furnace over that portion of the layer of fuel that required it, without interfering with the body of burning coke on the lower portion of the bars. To make this change involved a trifling expense and no loss of time for the kiln, as it could be done in the two days required for the drawing and setting of the kiln without interfering with either operation. Three arches were built into each furnace. For convenience of con-

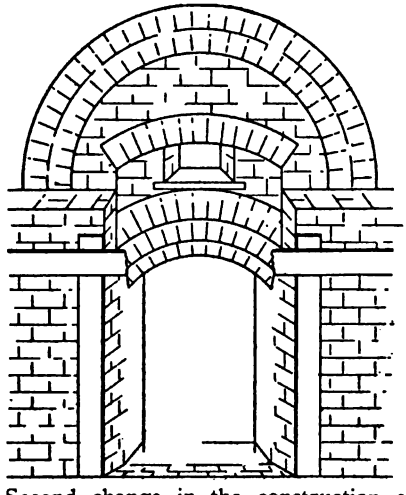


FIG. 23. Second change in the construction of furnace.

struction and ease of firing, they were placed low enough to avoid tearing out the old arches and also to leave room for a salting hole. It was customary in using the old furnaces to salt through the charging hole, but the lower arches of the altered furnaces left insufficient room to do this conveniently. The bars were lowered to correspond to the location of the arches, and the furnace bottom lowered to make as much vertical room as desired.

We use the furnaces that have been so altered with satisfactory results. The roof of fire brick located just above the fuel bed and sloping downward with it, serves a

triple purpose: First, it forms over the fuel a confined passage through which the air admitted there must pass, bathing and igniting the coal, besides mixing with the gases evolved and combusting them. Second, the combustion thus encouraged keeps the brick arches hot and they in turn help to heat the air as it passes between them and the burning fuel. At the same time the air is given a better opportunity to mix with the fuel gases, as both pass under the arches together. Third, after each firing the heat radiated to the fresh coal starts it roasting immediately and the coal not only ignites quickly over all the upper surface, but the heat of the combustion, being in part reflected back against the coal, cokes it deeply, preparing it for a hotter berth lower on the bars after the next firing.

We thus have two distinct fires in the same furnace: First, the coke fire on the lower portion of the bars, in which the air for combustion is drawn upward through the mass; second, the fire which kindles quickly on the surface of each baiting of coal and is fed mainly by the gases roasted out of the coking mass. The products of combustion from these two sources are thrown together in the lower portion of the furnace and mix as they pass upward through the bag.

When the burners began to fire the kilns with the new arches they learned to follow a practice somewhat different from that followed with the old ones. They had been burning with fires nearly closed, because the kilns heated better so. Open firing did not give the desired result, for the reason that the air admitted over open fires could not be so treated as to fulfill its function in the furnace. It was therefore necessary to keep thin fires on the bars so as to let free oxygen through the hot mass at the bottom to help take care of the gases evolved by the fresh coal above. With the newer arrangement, the burners do not have to be told to carry open fires. They have learned that the kiln heats better if the fires are not tightly closed. In firing, they ram nearly all the fuel to the bottom, making

a layer that just falls short of closing the space under the lower arch. This leaves room for the new charge of coal at the top, but does not permit the influx of a big rush of cold air while the coal is being heaved in. A slight economy is effected by this check. They then throw in the coal

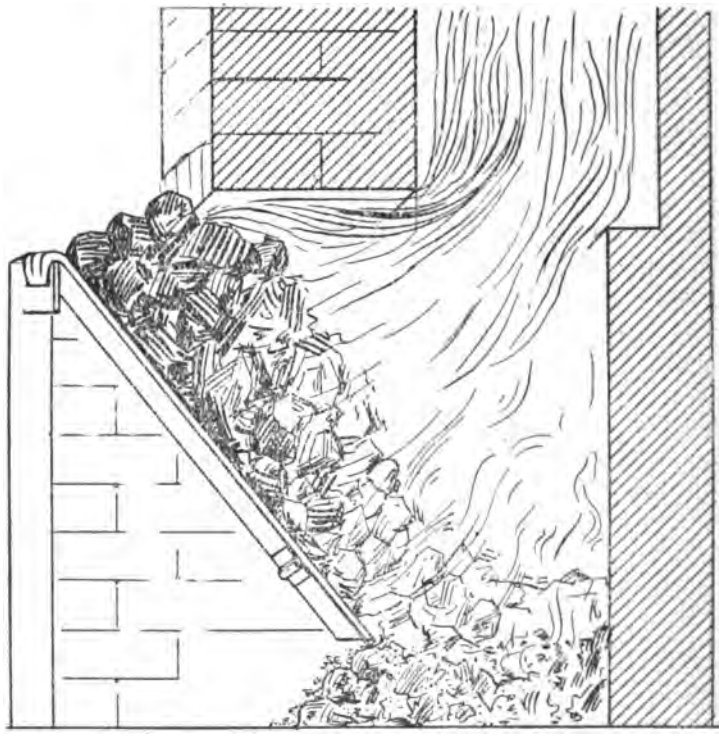


FIG. 24. Faulty conditions for combustion.

in such a way as to leave a considerable hollow between the first and third arches, and a space of perhaps an inch is left open under the span of the top arch.

Immediately after firing, the freshly broken mass at the bottom makes a great disurbance and the air squad let in through the upper passage is kept busy quelling the riot. By the time the excitement is over in that quarter,

the roasting above has gotten under headway, and the fresh air must get busy nearer home. The furnace wasn't trained to keep matters equalized in this way, it does it by instinct. Of course the burner is there to see fair play, and he can easily tell whether to have more or less inlet

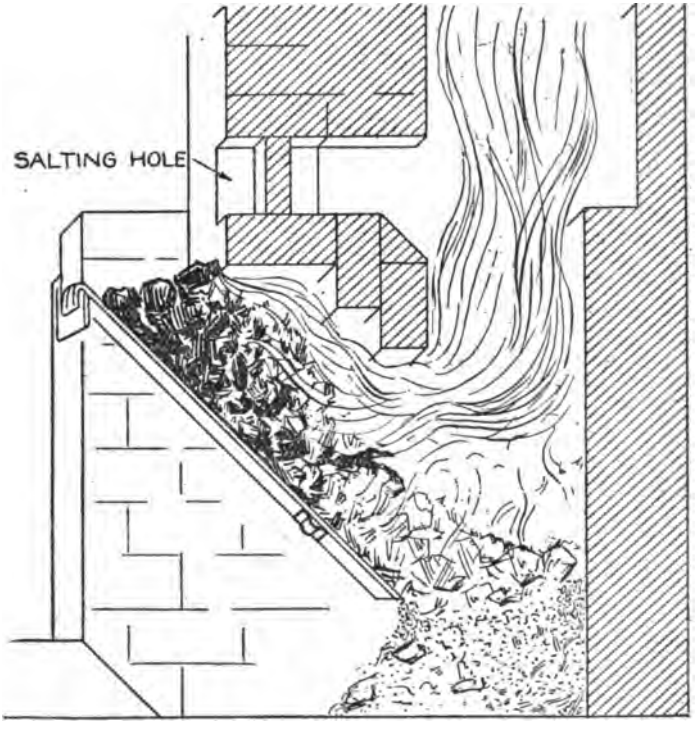


FIG. 25. Improved conditions of combustion in altered furnace.

space over the coal. During the oxidation period he lets in a good deal more than is required for combustion. After the ware is oxidized through, he lets in just as little as will do the work. But in either case he can get the desired condition without difficulty, and the average burner will get results that are more uniformly good in a kiln where he can get the right conditions easily than in one

where he has to work hard to get them at all. Figures 24 and 25 show the faulty and satisfactory firing conditions discussed above.

DISCUSSION.

Mr. Yates: This introduces a new theory. My experience has always taught me that you want to keep your air back of your fire. I would like to know, with a slanting bar of that pitch, how he proposes to clear the fire, or, whether he considers it necessary to clear the fire?

Mr. Hull: I will have to ask Mr. Yates for a definition of just what he means by "clearing" the fire. I do not quite understand.

Mr. Yates: You put your coal on and have a carbonaceous flame. If you are making salt-glazed pipe, do you consider it necessary to produce an oxidizing fire before you use the salt?

Mr. Hull: Not only just before we use the salt, but thirty-six hours before we use the salt. We keep the fire running that way as nearly as possible. The trouble with the old furnace was that we were not able to keep a clear fire all the time. With our improved furnace, if a burner sees anything but a clear fire for more than five minutes, he thinks he has made an error in judgment.

Mr. Yates: How do you propose to rake the fire? That is my understanding of clearing the fire.

Mr. Hull: The intention is for this furnace to be an automatic cleaner and we don't use the term "rake" at all.

The Chair: I think this contribution is very valuable, insofar as it comes close to what was said last night about the gas producer. The arrangement of the fire box on this plan gives the highest benefit of which the coal we are using is capable. This style of furnace does not need raking. It is a continuous process, and the ashes below need only to be shoveled away.

NOTE ON A HIGH-ALUMINA FLINT CLAY.

BY

A. F. GREAVES-WALKER, Salt Lake City, Utah.

Very little has been written on the subject of the flint fire clay deposits of northeastern Kentucky. This is probably due to the fact that they are still comparatively new and but little known, and also because Kentucky has not had a state geologist or a geological report for many years.

The deposits cover several counties, but as yet have been developed only in Carter Co., the center of the fire clay industry in that county being Olive Hill, of late quite celebrated for the high grade of its products.

The deposits near Olive Hill are truly wonderful in many respects. They often run from 20 to 30 feet in thickness over a large area, the entire vein being flint clay of great purity.

In the famous Burnt House Mines of the Olive Hill Fire Brick Co. may be seen several varieties of high grade flint clay in the same vein, these ranging from high silica to high alumina, the major part, however, being a clay with equal parts of each.

Each variety is distinctly different from the other, and no trouble is experienced in keeping each kind separated from the others.

It is with the high alumina variety that this note especially deals, however, for in this we find something very uncommon, as will be seen from the following analyses:*

Note. — A number of reports of analyses for this paper were accidentally destroyed and could not be replaced.

No.	Silica.	Alumina.	Ferric Oxide.	Lime.	Magnesia	Loss on Ignition.	Total.
1	39.56	43.35	2.57	0.56	0.50	13.09	99.63
2	34.76	48.50	1.26	0.76	0.11	14.08	99.47
3	39.01	42.01	4.04	0.68	0.45	14.00	100.19
4	37.21	43.76	3.53	0.88	0.06	14.12	99.56

Locally this high alumina clay is known as "aluminite." It occurs at the top of the vein, lying on the ordinary No. 1 flint clay and generally separated from the sandstone roof by a thin stratum of dark impure flint clay which adheres to the rock when the "aluminite" clay is taken down.

It occurs in large blocks of various forms, though generally egg-shaped, each weighing from 500 to 5,000 lbs. and averaging about 2,000 lbs. In thickness it ranges from 3 to 20 feet. It is extremely hard, resisting everything but the heaviest two-man auger machines. In mining, it is first left in position, the No. 1 flint clay being taken from beneath it as the room or entry is driven ahead. When sufficient clay has been taken from beneath it, a 6 foot hole 2 inches in diameter is bored and tamped with about 4 feet of powder and dynamite. Such a shot will often knock down 175 tons; the large blocks are then either broken with a heavy hammer or shot open. When left up in the mine it makes an excellent roof, for unlike other flint clays it is not affected by the atmosphere and will not slake, even when immersed in water for long periods.

In appearance it is different from the ordinary flint clays. In color it is light brown and it breaks with a rock fracture instead of a concoidal fracture like other flint fire clays. The surface of a fracture is very rough, being covered with small sand-like granules, about the size of a pinhead. It is to the presence of these particles or granules that this clay owes its high alumina content, they being pure aluminum oxide.

The amount of alumina, therefore, depends on the number of these nodules. In some parts of the deposit they are so numerous as to occupy all available space, the clay looking like fish roe, in which case the alumina runs very high, and the iron low, while in other parts they are merely sprinkled through the clay matrix, the alumina in this case being only slightly higher than the silica, and the iron running high. The clay matrix which contains these nodules analyzes the same as the regular No. 1 flint clay beneath it in the vein, except that the iron content is very much higher.

The presence or origin of these nodules is hard to explain. It is probable, however, that during the formation of the deposit, beauxite or some kindred mineral was carried into it in small particles, they becoming scattered through and imbedded in the clay.

On burning a block of this clay to about cone 12, no cracks or checks appear, and the matrix is of a dark brown color, due to the iron, while the nodules are all pure white.

Probably the most striking property of this clay is its refractoriness. In the Deville furnace it has stood time and again with cone 36 down. At this temperature the trial cone would be perfect, but jet black. Used as a lining for a Deville, it outlasted even magnesite. It stood temperatures far above cone 36, while exposed to abrasion from both fuel and blast, without any apparent effect.

This clay is a striking illustration of the predominating influence of alumina over the fluxes, the small percentage of alumina in excess over 40% being seemingly able to counteract all of the fluxes, leaving the remainder of the alumina to combine with the silica, a combination able to withstand temperatures equal to the best refractory clays in the world. This is the more striking when it is known that this vein will average nearly 4% ferric oxide.

As before stated it is extremely hard, and plays havoc with anything but very heavy crushing machinery, but when crushed and put through a medium fine screen a great deal of latent plasticity can be developed by a wet

pan treatment. Its shrinkage is the same as that of the other flint clays in the deposit, amounting to 10 per cent.

Bricks made from this clay burn to a reddish brown color at cone 12, and at this temperature are very dense and hard.

Being naturally basic, it is extremely valuable where a basic fire clay brick is necessary, such as in rotary cement kilns, lime kilns, copper converters and reverberatory furnaces, lead blast furnaces and settlers; in these two latter, especially from the slag line to the hearth or bottom. It has also proved itself the equal of any brick, when properly made, for the bungs of malleable iron furnaces.

With this natural example of what a small percentage of alumina can do, in improving a high grade fire clay, both from a refractory and chemical standpoint, it will not be hard for the high grade fire brick makers to add a small per cent. of bauxite to an already good clay to make it better. Bauxite is still plentiful in Georgia, Alabama, Arkansas and Arizona, and there can be little doubt but that a small quantity added to a brick mixture will overcome a great many difficulties.

THE CONSTRUCTION AND OPERATION OF A DEVILLE HIGH TEMPERATURE FURNACE.

BY

A. F. GREAVES-WALKER, Salt Lake City, Utah.

In the last few years it has become imperative that the manufacturers of high grade refractory materials should test the refractoriness or heat resistance of their products from day to day. This necessitates a testing furnace that will give accurate results quickly, at the same time one that is easily handled and controlled.

There are many kinds of high temperature furnaces, such as electric furnaces, or those using gas, oil, coke and carbon as fuel, but only one or two have ever been developed that will attain temperature of 1850° C. Seger cone 36, and it is such a temperature a test furnace must reach in order to give satisfactory services.

The electric furnace seems to offer nothing practical as yet, for although there are furnaces that will attain a high temperature at the arcs, they are not practical for clay-testing purposes.

Gas, gasoline and oil furnaces can be had that will reach temperatures as high as cone 33, but these furnaces have not as yet been found generally useful at temperatures above cone 28 or 30.

This leaves us only the coke or carbon furnaces to consider, and without doubt the Deville furnace stands at the head of this class of furnaces.

It is with the Deville furnace that this paper will deal and the writer will endeavor to set forth its construction and operation. A very excellent paper on this subject was written by Prof. H. O. Hofman of the Massachusetts Institute of Technology and read before the American Institute of Mining Engineers, in 1895. Very little can be added to this paper, but the subject is of such interest to our industry that it will not be amiss to treat it in our transactions.

The points in favor of this furnace are: Its simplicity, easy and cheap construction and its ease of operation. There is really but one disadvantage, and that is that the trials cannot be seen while the operation is going on, so that the results are known only after all the fuel is consumed and the test completed.

The Furnace.

The furnace, represented in the following plate is an iron cylinder, which is best made by taking an 18-inch length of 10 inch malleable iron pipe. This cylinder is lined with some refractory material. It is open at the top and closed about 4 inches from the bottom by a perforated plate. The space below this plate is the air chamber, into which leads the blast pipe. The bottom of this air chamber is closed and made air tight by setting the furnace on an iron plate, the place where the furnace and plate meet being luted with a non-shrinking clay.

For the refractory lining material several substances can be used, bauxite, magnesite, a bauxite-clay mixture, a carborundum-clay mixture or a very refractory flint fire clay to which has been added a small percentage of aluminum oxide.

Calcined bauxite, as a lining, can hardly be improved on, for it is extremely refractory and easily prepared. The raw bauxite, which is practically pure aluminum oxide, must be calcined to at least cone 16 before using, as its shrinkage is very great up to that point. In preparing it for a lining material it should be crushed to from 12 to 16 mesh; it can then be mixed with about 3 or 4% of slaked lime, mixed as a milk of lime, which will cause it to set and assume great hardness, or with about 20% of a plastic fire clay, which will also make a good body.

If magnesite is used, it should be crushed to pass à 4 mesh sieve, and wetted down with from 8 to 10% of hot water. It should then stand for 2 or 3 days to allow of complete hydration. It is then mixed with sufficient water

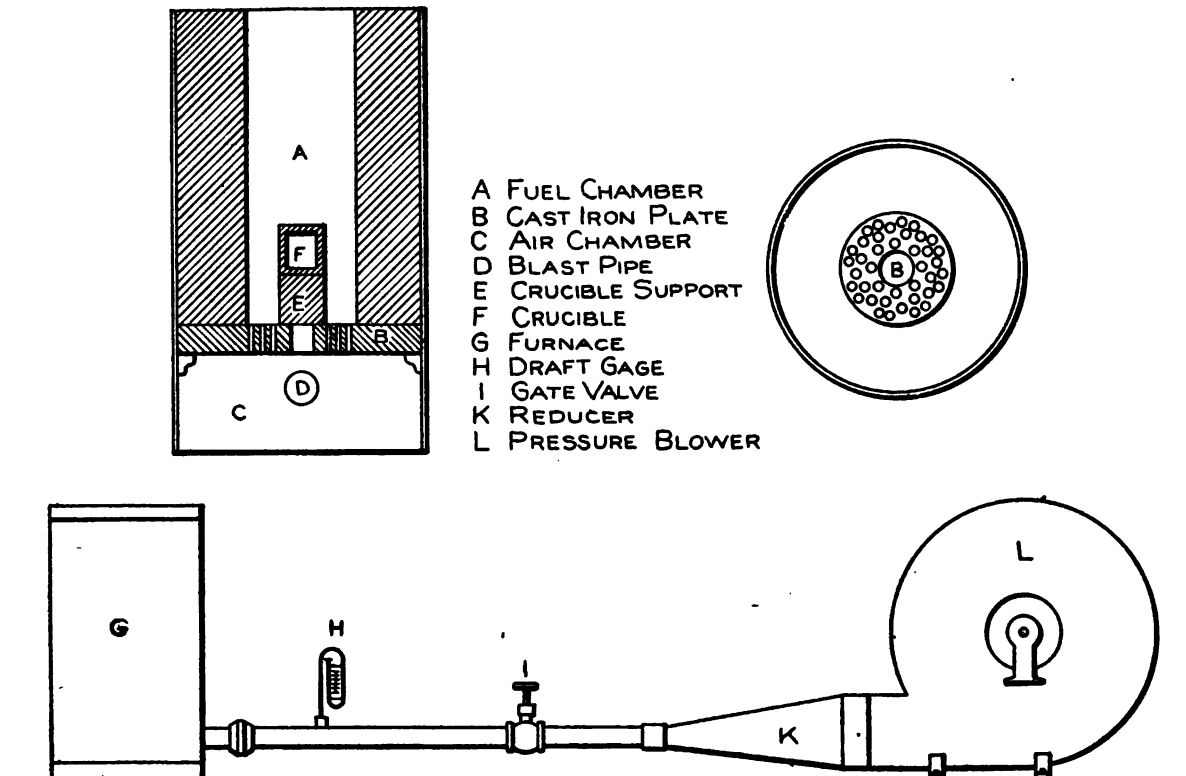


Fig. 26. Illustrating construction of Deville furnace.

to make it bond when squeezed in the hand and is ready for use.

A mixture of 50% finely ground carborundum and 50% plastic fire clay makes a fairly good lining, but in the writer's experience it is the poorest of the lining materials mentioned.

If a good refractory flint fire clay is available, a very good lining can be made by grinding it fine and adding 15 or 20% of commercial aluminum oxide. This mixture can be worked until it develops a fairly plastic body and makes a good dense refractory lining.

The advantage in using the last mixture, as is also the case with the other clay mixtures mentioned, is that when that part of the lining which is subjected to the highest heat, slags away, it can be repaired by filling up the hollow and smoothing up the sides with a little of the raw material, which will stick and burn to the original lining during the next heat.

On the other hand, a magnesite lining or a bauxite lime lining must be entirely replaced when partially burned away.

The lining material is tamped around a wooden core, the shape of a truncated cone, 18 inches long, 4 and 3½ inches in diameter. It should have a spindle in the middle of the small end. This fits into a large central opening in the grate and holds it in proper position.

The core should be wrapped in five or six thicknesses of newspaper, the last being fastened with mucilage to prevent it from unwrapping. The material is added in layers, each layer being tamped down with a stick. When the lining is complete the core is removed by tapping the spindle projecting through the hole in the grate. This will force it upwards, leaving the paper sticking to the lining. The paper is easily removed when the lining is dry, the drying process requiring several days. When bone dry, a light wood or charcoal fire should be kept in the furnace for 8 to 10 hours; it is then ready for use.

The Blower.

The blower best suited for this furnace is a No. 3 Buffalo pressure blower. It has ring oiling bearings and a 4¾ inch outlet. It should be belted to run from 3,200 to 4,000 revolutions per minute. A half horse power motor was found very convenient in connection with this blower. The outlet is connected with the one inch pipe by means of a fish horn reducer made of galvanized iron, on the small end of which is soldered a one inch sleeve.

The Draft Gauge and Valve.

A low pressure U draft gauge, measuring pressures up to 2 inches of water, answers the purposes. Such a gauge was supplied by the B. F. Sturtevant Co., Boston, Mass.

The blast is controlled by means of an ordinary one inch gate valve, inserted midway between the blower and the furnace. Such a valve gives easy and complete control.

The Crucible and Support.

The crucible (f), in order to stand the intense heat of the furnace, must be extremely refractory material. A mixture of bauxite and lime, as described for the lining, or a mixture of 50% bauxite and 50% high grade refractory fire clay makes an excellent crucible. Instead of using bauxite in the above mixture, pure calcined aluminum oxide may be substituted. When clay is used, at least 90% of it should be calcined, 10% being left to bond the calcine and either the bauxite or oxide. Crucibles made of the above mixture are absolutely untouched at cone 36. They can be easily made by pressing in a plaster mould. The covers are batted out of the same material and cut to size. The writer found that the calcined ingredient should be ground as coarse as the thickness of the crucible will stand.

A very good crucible is made by grinding together 50%

aluminum oxide and 40% calcined fire clay until 75% of the mixture will pass a 12 mesh sieve and remain on a 16 mesh, the remainder passing through the 16 mesh. To the entire mixture is then added 10% of finely ground plastic fire clay.

Such a crucible will often stand from four to five tests, and the writer had one which stood ten before it cracked. The support should be made of the same material as the crucible. Both crucibles and supports should be burned before using, as they are likely to break from the weight of the superimposed fuel, if used raw.

Crucibles and supports can be obtained from W. G. Hipp, of the Massillon Stone and Fire Brick Co., Massillon, O.; Eimer and Amend, New York City, and the Thonindustrie Zeitung, Berlin.

Cones.

The cones used are the small standard German cones, measuring $\frac{3}{8}$ inch across the base and 25/32 inch in height. The cones to be tested should be of the same shape and dimensions approximately. They can be made in a mold of the proper shape and size or molded with the fingers. With a little practice the latter method is quicker and just as accurate as the former.

The material to be formed into cones should be ground to pass a 200 mesh sieve, and almost any material, whether possessing much plasticity or not, will take a good shape when in such a fine state. If calcined clays or brick are to be tested the samples are ground to the above fineness and mixed with a little diluted fish glue; they are then easily molded. The method of chipping off a sample of the brick and testing it against a cone is to be avoided if accurate results are desired, as unquestionably, any great difference in shape or size of the cones tested will affect the melting point from one to two cones. However, when a mere working knowledge or rough test is all that is required, a small chip taken from a brick will

answer. When this is done an effort should be made to have the sample as near the size of the cones as possible.

Grinding the sample very fine does not affect the melting point of a high grade brick in the least, and does not affect the melting point of any single clay or other refractory, whether of high or low grade. This will be seen by referring to the paper by H. O. Hofman and B. Stoughton, read before the A. I. M. E. at Buffalo in 1898. The experiments described in that paper have been fully verified by the writer.

It is best to place about five cones in a crucible at one time, three standard and two test cones, but as many as seven or eight can be put in at once, by crowding. A little base is made, into which the cones are stuck. This base is a small pat of refractory clay, $\frac{1}{4}$ inch thick, that will fit inside the crucible. To keep this base from sticking to the crucible, aluminum oxide is sprinkled over the bottom. A chart of the position of the cones should always be kept, the position of the rest of the cones being referred to the highest standard cone used. This cone will be easily recognized even when they are all badly melted.

It may be found that instead of turning over, as do the larges cones, the small ones used will gradually sink within themselves when their melting point is reached, forming a small globule. After a number of experiments the writer found that cones acting in this way are "down," i. e., the temperature they signify has been reached, when they measure one-half their original height.

Fuel.

The fuel used in this furnace is gas carbon, a hard dense fuel, containing less than 0.1% ash. It is crushed to pass a two mesh and the fines removed on a 4 mesh sieve. A small laboratory crusher is best for crushing this material, although it can be done in an iron mortar.

Charcoal is used to ignite the carbon, it being crushed and screened to the same size as the latter.

The amount of carbon necessary for a test depends

upon the furnace, the temperature desired, and the amount of blast. As a general thing, about 2½ lbs. of carbon should be ample to reach cone 36, with a furnace of the dimensions herein given, and with an air pressure equal to 2 inches of water. It would, of course, require less fuel for lower temperatures.

The gases from the fuel are drawn off by means of a hood supported over the top of the furnace and connected with a flue. This hood should be made so that it can be moved aside, thus giving easy access to the interior of the furnace.

Operation of the Furnace.

The crucible support is placed exactly over the large central opening in the grate and the crucible placed on it.

A handful of excelsior or torn newspaper is then dropped around them and fire applied, just sufficient blast being used to cause the excelsior or paper to burn nicely. When well started, charcoal is added, enough to completely cover the top of the crucible, about ½ pound; the blast is then raised to ½ inch.

When the charcoal is well ignited, the first scoopful of carbon is added and the blast pressure raised to one inch. The carbon should then be added a scoopful at a time, each scoopful being added as the preceding one becomes a dull red throughout. Each addition should not increase the thickness of the bed more than 1½ or 2 inches. As the carbon is added, the blast is gradually raised until 2 inches pressure is reached. The pressure is then maintained at this point until the carbon is entirely consumed. This requires an increased amount of blast as the carbon burns away.

It must be borne in mind that the foregoing figures will vary slightly with each furnace, and with each different temperature required. However, using ½ pound of charcoal, 2½ pounds of carbon and following the above pressures approximately, should give cone 36 in a furnace such as is herein described.

In order to get good results, a new furnace must first

be standardized, i. e., the amounts of carbon and pressures determined for each cone. This can be easily done, and with this knowledge once obtained, a more satisfactory furnace could not be found.

Fusion Tests of Seger Cones.

The following table, taken from Prof. H. O. Hofman's paper, will be found very helpful when standardizing a new furnace.

No.	SEGER CONE: Form after Fusion	SEGER CONE: Luster after Fusion	FUEL-CHARGE: Paper, grams	FUEL-CHARGE: Charcoal, gms.	FUEL-CHARGE: Gas-carbon, gms.	FUEL-CHARGE: Time of feeding, minutes	BLAST PRESSURE: Inches Water at Minutes after Starting: Inch	Min.	Inch	Min.	Inch	Min.	Inch	Min.	FURNACE: Initial Condition at Time of Starting	Appearance of, in Minutes after Starting: First CO Flame	Steady CO Flame	Crucible in Sight
26	Beaded	Dull	30	200	900	6	0.5	1	1	3	.....	...	....	....	Cold	8	10	37
26	Globular	Dull, vitreous	30	200	925	7	0.5	1	1	7	.....	...	.	....	"	13	18	3
26	Lenticular	Vitreous	30	200	950	7	0 5	1	1	7	.....	....	...	....	"	13	18	38
27	Globular	Dull	30	200	925	7	0.5	1	1	7	. ...	...	....	....	"	13	18	85
27	"	Dull, vitreous	30	200	950	5	0.5	1	1	7	.....	....	...	....	"	13	18	38
27	Lenticular	Vitreous	30	200	995	7.5	0.5	1	1	6	1.5	17	....	....	"	19	28	41
28	Shortened	Dull	30	200	925	7	0.5	1	1	7	.....	....	...	...	"	13	18	35
28	Lenticular	"	30	200	950	7	0.5	1	1	7	.....	....	...	....	Hot	13	18	38
28	"	Vitreous	30	200	925	6	0.5	3	1	6	1.5	12	..	....	"	12	13	35
29	Globular	Dull	30	200	900	6	0.5	1	1	3	1.5	6	....	...	"	11	12	29
29	Lenticular	Vitreous	30	200	925	6	0.5	1	1	3	1.5	6	....	....	"	12	13	35
29	"	"	30	200	1000	6	0.5	1	1	3	1.5	5	....	.	"	15	17	45
30	Shortened	Dull	30	100	900	6	0.5	2	1	3	1.5	6	....	....	"	11	12	29
30	Lenticular	Dull, vitreous	30	200	925	6	0.5	1	1	3	1.5	6	....	....	Cold	11	14	28
31	Globular	Dull	30	200	925	6	0.5	1	1	3	1.5	6	....	....	Hot	12	13	31
31	Lenticular	Vitreous	30	200	925	6	0.5	1	1	3	1.5	6	....	....	Cold	10	11	29
32	Shortened	Dull	30	200	925	6	0.5	1	1	3	1.5	6	....	...	"	11	14	28
32	Globular	"	30	200	1025	6	.....	1	1	3	1.5	6	....	....	"	11	13	31
32	Lenticular	"	30	200	950	6	0.5	...	1	1	1.5	6	2	17	Hot	10	12	30
33	Shortened	"	30	200	1025	6	.....	....	1	1	1.5	6	....	....	"	11	15	36
33	Lenticular	"	30	200	1050	6	0.5	2	1	3	1.5	6	....	....	"	12	13	35
33	Globular	"	30	200	925	6	0.5	1	1	3	1.5	6	2	17	Cold	10	14	24
34	Beaded	"	30	200	925	6	0.5	1	1	3	1.5	6	....	....	Hot	10	11	25
34	Globular	"	30	200	925	6	.....	...	1	1	1.5	6	2	17	"	9	11	29
34	Lenticular	"	30	200	975	6	.....	..	1	1	1.5	6	2	17	"	10	11	?
35	Beaded	"	30	200	925	6	.....	....	1	1	1.5	6	2	17	Cold	?	17	26
35	Globular	"	30	200	925	6	.....	...	1	1	1.5	6	2	17	Hot	9	11	29
35	Lenticular	"	30	200	1000	6	0.5	1	1	3	1.5	6	2	17	"	8	10	25

When the fuel is all consumed and the crucible plainly visible, the blast is turned off, and the crucible lifted out with a pair of long handled crucible tongs, shaped to fit.

The lid and base will invariably stick to the crucible, but the lid can be easily removed, without breaking, by tapping the edges with a flat file or chisel.

Cost.

A furnace of this description should not cost, complete, with blower and gauge, over $25.00, and when once installed needs little or no repairing.

CERAMIC EDUCATION IN ILLINOIS.

BY

ROSS C. PURDY, Champaign, Ill.

Ceramic education in this country is not a matter of a decade, but rather of almost three decades. Twenty-eight years ago, the Illinois Clayworkers' Association was organized. Two years later, the Ohio Drain Tile and Brick Association came into existence. In 1886, twenty years ago, the National Brick Manufacturers' Association met in Cincinnati, Ohio, for the first time, inaugurating the work that in time found fruitage in the valuable work done by Prof. Edward Orton, Jr., as secretary of their Committee on Technical Investigation. Ohio, Illinois, Nebraska and Iowa have had organizations of clayworkers and some are now doing very good work in the interest of higher ceramic education.

There is no greater evidence of the good these states and national organizations of clayworkers have done, than in making possible the establishment of ceramic schools and departments in our Universities. If it were not for the earnest desire to have settled the many mooted questions that came up for discussion year after year, and if the clayworkers had not thus been led to see the possibilities in technical ceramic training, it is doubtful whether our first ceramic school could have been established ten years ago.

To Prof. Edward Orton, Jr., must be given the credit of seeing and seizing the opportunity made ripe by the work of the clayworkers' associations, and carrying to a successful issue, in 1894, a movement in Ohio for the establishment of a ceramic repartment in the Ohio State University.

The impetus given to ceramic education in the United States by the organization of this department is inestimable. There is doubt whether the American Ceramic

Society would have begun its fruitful existence seven years ago, were it not for Prof. Orton and his pupils. A glance through the table of contents of our transactions reveals the active part he and his students have taken in the dissemination of technical ceramic knowledge.

Surveys.

Considerable credit must be given to the work of our United States Geological Survey and the several state surveys for the most valuable aid they have rendered by scattering abroad, in a very effective way, ceramic information, especially from the geological standpoint. Prof. George H. Cook, in his reports on the clay deposits of New Jersey in 1878, and Prof. H. A. Wheeler, in his report on the clay deposits of Missouri in 1896, gave us the first concise and the most complete treatises on ceramic technology.

Publications.

In 1895 Mr. Karl Langenbeck published his "Chemistry of Pottery," the first book in the English language that discussed the application of chemistry to ceramics. Together with a few translations of foreign works, the survey reports by Cook and Wheeler and "The Chemistry of Pottery" were the early foundations of our technical ceramic education in this country. With these works as a basis, backed by the trade journals, encouraged and assisted by the Association, our first graduates pioneered their way against the stolid opposition and prejudice of the old-time clayworkers.

Broadmindedness of a Few Clayworkers.

That all of our wide awake and progressive clayworkers were not to be found in the various associations was forcibly shown when the time was ripe for the founding of this Society. The many contributions to the ceramic literature in our transactions by potters and brick manufacturers who had not had the privilege of a special

ceramic training or who had not affiliated with any association, bear evidence that there was ample ground and that the seed of progress was well sown, the harvest of which is represented by seven matchless volumes of ceramic literature and four schools of ceramic technology.

No small amount of credit must be given to our broad-minded fellow ceramists who dared to place in educational exhibits at our recent World's Fair a detailed description of their processes of manufacture together with formulae of body and glaze. Our several letter files contain not a few letters from such men as our esteemed fellow member, Mr. Ernest Mayer, teeming with practical observations, given unreservedly.

Much credit must also be given to our public men, of whom Dr. Cushman ranks high in our esteem, for their prolific researches and publications.

Our friends across the waters we must credit with much that has influenced and advanced our ceramic education. Much of the initiative in original research comes from such men as Seger, Bischof, Hecht, Le Chatelier, Cramer, Vogt, Brongniart, Zulkowski, Richter and others.

Clay Journals.

Our clay journals, although not having attained or attempted much in the more technical fields, must be recognized as factors that have done much to pave the way for the advancing technical ceramist. They have done much to shape the views of the so-called "practical" clayworkers in our favor.

Expositions.

Time and space do not permit the enumeration of all the forces tending to advance technical ceramics in our country, but a passing word should be said concerning the value of expositions. Technical ceramics has derived great benefits from expositions where the best ceramic products of all countries have been displayed, inciting us on to newer and better achievements. Justly proud of our own

exhibits, we have not failed to appreciate the merits of those of other countries and to receive fresh inspirations from them. The exhaustive consideration of the things learned from the St. Louis Exposition in our last volume of transactions makes superfluous further comments at this time.

Schools.

The great forces directing and promulgating all of this new and stimulating activity in technical ceramics in the United States are our schools. This was very forcibly brought home this year in the Illinois Clayworkers' Association held in Champaign, Ill., January 23, 24 and 25. Last year, at the instigation of Prof. C. W. Rolfe, this association appointed a legislative committee which went before the State Legislature and secured the passage of bills providing for a department of ceramics in the University of Illinois and also a clay survey of the state by a Geological Survey Commission now under the directorship of Dr. H. Foster Bain. This year the association again met in Champaign, reappointed the legislative committee to further the legislative interest of the ceramic department and survey, and passed resolutions expressing their approval of what had been accomplished and asking for a two weeks' school preceding the convention week, when the clayworkers, too busy and too much involved to spend a longer period in school, can learn some of the late methods of measuring and controlling their various factory operations, as well as testing and identifying clays, familiarizing themselves with the geology of their state and obtaining an insight into the processes in vogue in the several lines of ceramic work. This year's convention was the most enthusiastic and the best attended of any in their history. Many lines of ceramic work were considered and deep interest was evinced by all in the several topics discussed. This awakening to the value of ceramic training argues well for the future of technical ceramics in Illinois. Because the enthusiasm in the "Sucker" state will be felt in all states, and their endeavors mark a decided advance

in technical ceramics in the country at large, a record of what they purpose to do in their School of Ceramics should find a place in our transactions.

Short Course.

Not losing sight of the many advantages to the clay-worker of formally giving a two years' course in ceramics, it was deemed imprudent to offer such a course in the University of Illinois.

While there have been many whose entire collegiate training in ceramics was in the studies offered in the short courses and who have been of great credit to their *alma mater* by the success that has attended their efforts in the practical field and by their many valuable contributions to our literature, there are many short-course men who are not of that caliber of mind to command respect or to win success either in factory or laboratory. The manufacturer does not look very far into the history of the short-course graduate. He considers him a college graduate in ceramics and expects great results. As a rule no distinction is recognized between the two- and four-year men. Both are ceramic graduates from a reputable university and in this regard both are on an equal footing in the minds of the clay manufacturers at large. As a result, the incompetency of a large number of the two-year men reflects to the discredit of the four-year graduates. This will be inevitable until our manufacturers learn to discriminate between the two classes and give credit where it is due.

There are two principal reasons why the two-year man should not be allowed to pose wittingly or unwittingly as a ceramic graduate. The requirements for admission to the short courses are virtually equal to or less than those required to enter our high schools. This is obviated to some extent in the Ohio State University by requiring that the applicant must either be twenty-one years of age or must have had two years' practical experience. Before this rule went into effect, many young men took this short

cut to college and to their life work, passing out of college in the majority of cases, without having completed the two years' course, and lacking the broadness of intellectual development and acquaintance with that which will be expected of them in factories to which they go as expert ceramists. Notwithstanding the constant and forceful exhortations to all, that they make a humble beginning so as not to overreach and betray the confidence of their employers, the majority assume ability and knowledge and many fail. The fact of the case is, many who have attended a ceramic school for a short time and not completed either required course, have obtained employment on the strength of their having attended this or that ceramic school, and their employers, taking it for granted that they have completed a course, engage their services. The history of a large number of such cases is such as to cast serious reflection unjustly on the efficiency of the particular school in question.

In the second place, the two year man is not a university man except that he has taken some collegiate work. The bulk of his curriculum must be of high school grade, and, properly speaking, he should be classified as a preparatory student taking some college work in a particular line.

To officially grant the two-year man a diploma, even though it may specifically state that it is only a certificate of work accomplished, puts the two-year man in a position to claim that he finished a course and received a diploma, which to many managers of clay-working plants means that he is a full-fledged graduate.

To ameliorate and obviate these evils to as large an extent as possible and yet give the man who has neither the time nor the preparation to take a full four-year course in ceramics the opportunity to study the technical phase of this subject, the University of Illinois has made the following ruling:

"Persons over twenty-one years of age, not candidates for a degree, may be admitted to classes, after satisfying

the dean of the college concerned and the professor in charge of the department in which such classes are taught that they possess the requisite information and ability to pursue profitably, as special students, the chosen subjects. Such students are not matriculated; they pay a tuition fee of seven dollars and a half, a semester, in addition to the regular incidental fee of twelve dollars.

"After successfully completing thirty semester hours of university work, a special student may receive such credits towards matriculation on account of practical experience in the line of his course as the head of the department may recommend and the dean of the college may approve.

"This plan affords the student, with a limited amount of time, all the advantages of a short course, and at the same time secures a good grade of work in the subjects studied."

Rudimentary work in mathematics, physics, etc., may be taken in the preparatory department.

Long or Four-Year Course.

What should the curriculum of a ceramic department include? is a question which in most cases resolves itself into: What can be taken from the courses of study already given in the university that will be of value to the ceramist? This is brought about by a large number of interests that must be considered in the several departments. For instance, in geology there must be given special instruction for the liberal arts, science, agriculture and engineering students, and they cannot with justice be grouped together. In chemistry the several interests are still more manifold, and so it is throughout the university. To have special instruction in these several subjects for every department would require a large teaching force and unless there are sufficient students to warrant further specializing, it is found impractical to offer the best possible courses in the several curricula.

The general question, however, as to what training a

ceramist should receive, i. e., the amount and character of the engineering, pure science, mathematics, or the special training in ceramics, etc., should receive careful consideration. This leads to the question of whether ceramics should be considered as a science or an engineering course. Unquestionably it is largely applied chemistry and surely our graduates must have considerable engineering training in order to cope with all the problems that will confront them.

As a matter of history, those graduates who have a mechanical turn of mind, and particularly those who understand the installation and testing of machinery, boilers, engines, kilns, etc., are far better able to cope with the many factory problems. Conditions and processes require special equipment and peculiar arrangement of power transmission. Especially is this true in cement, glass, floor and wall tile, terra cotta, and brick factories. The principles of generation, distribution and controlling of heat, whether it be derived from steam, air, or direct combustion, require special treatment in the individual cases. The prospecting, estimating of the extent and value of new deposits of clays, the preparing of coloring oxides, etc., entail no little engineering skill. The designing and erecting of factory and kilns, or the making of additions thereto, as well as the understanding of the generation of power by either steam, gas or electricity, are problems involving engineering and must be solved by many of our ceramists. Therefore it is evident that a ceramic course of study must be strong in engineering.

Ceramic problems entering into body and glaze composition, coloring and opacifying, crystallation, determination of refractory value or adaptation of clays to particular purposes, the compounding of cement and glass mixtures, the controlling of the conditions peculiar to iron enameling, etc., are all problems in applied chemistry.

Tracing, identification and exploration of deposits of clays and minerals used in the silicate industries, are problems in economic geology.

Physics and mathematics are the fundamentals upon which the engineer bases all of his reasoning so they should find a large place in our curriculum.

Culture and the consequent broadening and refreshing of the mind should not be lost sight of, and, owing to the necessity for economy of time in the four years' course of study, we are compelled to give only those courses that will give the greatest benefit, and in the modern languages is found what is deemed the best and most practical. Modern languages, especially German and French, are essential to the best and highest development of ceramic education.

It is the artistic and commercial phases of ceramic training that are generally made to suffer in the crowded courses of study. It is not to minimize or deprecate their value and importance that they are not given more space, but rather because they are more dependent upon the peculiar make-up of the individuals. Art and business acumen can not be drilled in; they must be there as "second nature," a vague term that stands for so much. Those qualities that give to the individual taste for art and tact in business, must be inborn. True they are subject to training just as are those qualities that make a successful engineer or investigator, but, for general ceramic training, they do not seem to be as important.

Having considered what ceramic training should include, it is now possible to determine the status of a ceramic curriculum, i. e., is it an engineering or scientific course of study? Metallurgy has, by custom if not on its merits, been considered as an engineering study. If there is justification for classifying metallurgy as engineering, then ceramics should be similarly classified. They both deal with the application of chemical processes. The chemical processes involved are the essential considerations and the engineering phases entailed are only considered as a means to an end. Therefore there is justice to be found in either classification.

The amount and character of a purely ceramic train-

ing which should be given in a four years' course is a query partially answered by time limitation and necessity for giving a fundamental training in engineering and general sciences. Partially answered it is said, for there yet remains the problem of giving that which will soonest bring to the student an understanding of the fundamental ceramic principles. Can we make molds, form wares, decorate and, in other words, carry on factory processes? Can we make a full line of colors, blended on vases, or designed to be a part of some color scheme in tile or brick? Can we develop all types of glazes, enamels and body colorations each year? Fascinating as are crystalline and matt glazes, should they find a large part in the experiments conducted?

In the technical ceramic schools of Germany and France, all of these considerations may be realized, for they can cut here and there on the "accessory" studies, such as mathematics and engineering, favoring ceramics. In our universities it is different, for, as has been intimated before, special classes can not always be organized to meet the requirements of the few, but must be planned to meet the requirements of many. In this there are advantages accruing that greatly outweigh the disadvantages. Broadness of conception in the different lines of thought presented in the various courses is certainly acquired under our university conditions as it can not be where these accessory courses are cut to save time or adapt themselves more nearly to the needs of any particular group of students.

Even were our university conditions different, is it best to fully equip a young man to step into a responsible position in a factory at once, or is it best to give him only those fundamentals upon which he can readily train himself up to that degree of proficiency that will warrant his taking a larger part in the factory management? Personal initiative is one thing that must not be overlooked. Would body and glaze formulæ, necessary to the produc-

tion of a full line of glazed wall tile, be as valuable to the beginner as a thorough understanding of the problems involved, and the best methods of experimenting to develop a line of wall tile of his own? How much more dependent upon his notes than upon his own individual resources would a complete laboratory course in whiteware manufacture make the beginner? These are pedagogical problems that are ever before the instructor. We must look to the graduates for an answer to such queries. Judging from the unqualified success of the Ceramic Department in the Ohio State University, it must be said that the firm grounding in fundamental principles in school, leaving the application of these principles in the production of any given ware to the individuals, is a pedagogically sound method of instruction.

From many sources and not infrequently from members of the university faculties, we hear the opinion expressed that our university graduates to-day lack the originality and initiative that characterized those of a generation ago. Looking for the cause of this change we find that the courses offered to-day are more special and are conducted more nearly on a commercial scale. In other words, the student is given much more than the fundamental principles. I must admit that I am not personally informed on this point, but am repeating only what has been frequently stated. If there is truth in these hearsays, then we should profit by others' mistakes.

DESCRIPTION OF CERAMIC COURSES, OFFERED AT THE UNIVERSITY OF ILLINOIS.

1. *Classification and Physical Testing of Clays.* An elementary course designed to acquaint the student early with the varieties and the properties which adapt each to its special use in the ceramic industry. (3 hours.*)

In this course the student will be taught the geological

* An "hour" means an exercise which requires three hours of the student's time each week.

relations and differences of the several clays, and the influence of their physical and chemical properties in determining their adaptation to modes of manufacture and their suitability for given uses. Detailed physical and simple chemical tests sufficient to determine their general character will be made in the laboratory. A written report describing and identifying the clay and stating its possible value, will be required. The student will be encouraged to depend on his own resources as much as possible and finally to go out into the field, collect a sample of clay not known to be used and make a report on the clay as though to a commercial firm.

2. *Winning and Preparation of Ceramic Materials.* A study of the commercial methods of winning and preparing ceramic materials for the market and factory. (3 hours.)

This course is almost entirely a lecture course dealing with the methods of winning clay minerals, coloring oxides, and fluxes, and the processes of their preparation for ceramic purposes. Reasons for the necessity of different treatment of these materials or the reason why materials treated in a given manner are best suited for a given purpose will receive consideration in this course.

3. *Physical Calculations.* Problems and calculations relating to problems in hygrometry and heat, incident to the processes of drying and burning. (2 hours.)

This course will be in part a review of the fundamental heat phenomena, giving methods for mathematical calculation and measurement. Special stress will be placed upon heat balances of dryers and kilns and calculation of their efficiency. This course is intended to serve as an introductory course to the one following.

4. *Drying and Burning.* A detailed consideration of the methods of drying and burning clay wares, and the physical laws underlying these operations. (4 hours.)

This course is designed to be in a large part reference work. The general discussion of the principles of the various dryers and kilns will be followed by written re-

ports by the students on the several types, their uses and efficiency. By this means it is hoped to teach the student how and where to obtain specific information, as well as to acquaint him more effectively with the results obtained in various localities with the different types of dryers and kilns. In other words, the student will be encouraged and guided in obtaining information on the several details of dryers and kilns by his own efforts so far as possible.

5. *Body Making.* Lectures are given on the manufacture and body composition of various ceramic wares. Laboratory exercises are given to demonstrate the physical and pyro-chemical effect of variations in processes of manufacture and in composition; also to illustrate the peculiar properties and composition of the various types of bodies. (6 hours.)

Turning, jiggering, pressing and casting of the wares is encouraged but not required. Time does not permit of giving instruction in these processes of manufacture, but the student is requested to prepare ware to be decorated in the next laboratory course.

The lecture work includes a discussion of the manufacture of all types of clay wares, including description of methods, behavior of the clay or body undr various conditions, etc.

6. *Ceramic Stoichiometry.* Calculations involved in the manufacture of bodies and glazes, using Jackson's "Ceramic Calculations" and the "American Ceramic Society Manual" as a basis. (2 hours.)

7. *Glazes.* Lectures on the production of glazes and enamels, their classification, and the properties and defects common to each class, with laboratory exercises to demonstrate the fundamental characteristics of each type of glaze; the effect of variation in composition on its physical properties; and the mode of application. (6 hours.)

8. *Analysis of Glasses, Glazes and Clays.* (3 hours.)

9. *Colors of Bodies and Glazes.* Methods of opacify-

ing and coloring bodies and glazes, with detailed consideration of the methods of decorating clay wares. (3 hours.)

This is a lecture course.

10. *Ceramic Construction.* Original plans, specifications, and estimates of some ceramic construction will be required. (3 hours.)

11. *Cement.* A course of lectures on limes, cements and mortars of all descriptions, giving special consideration to the composition, reactions, and methods of manufacture, mining of the raw material, and testing of the finished product. (4 hours.)

12. *Thesis.* (8 or 9 hours.)

The Ceramic Department of the University of Illinois is offering two courses, one designed to lean more to the scientific side, in which ceramics constitutes thirty-one and three-tenths per cent.; the other course leaning more to the engineering phase, in which ceramics constitutes but twenty-three and seven-tenths per cent. of the total hours required. In other words, from a quarter to less than a third of the student's time is given to the special consideration of ceramics. A brick manufacturer, potter, cement manufacturer or glassmaker can not be developed in twelve months' time even under the most favorable circumstances. An apprenticeship is generally for three or more years, and a foreman, superintendent or manager can not become efficient in so short a time unless he has been developed by climbing rung after rung up from less responsible positions.

Why should manufacturers expect the graduates from ceramic schools to suggest at once better methods of factory manipulation, drying or burning, and to correct defects in ware in a month after his engagement, that have succeeded in worrying the manufacturer for months and years without finding a solution? Four years of study of ceramics! It is to be hoped that the time is not far distant when the manufacturer will realize what those four years really mean. Figuring nine months to a college year, four years of a ceramic course actually means from

eight and a half to eleven and a quarter months of ceramic work, and that, too, largely class room work. Yet the history of those who have graduated proves that with only that eight and a half to eleven and a quarter months' preparation, they can with success readily turn to any of the ceramic industries, from iron enameling or whiteware down to the commonest of brick and tile manufacture. There is hardly a problem in art ware or terra cotta that they have not or can not solve in a very reasonable length of time. The reason for this versatility? The reason must be sought in the firm grounding in the principles underlying ceramic operations and not in the skill of the artisan developed by manipulation of machines or tools.

When student and manufacturer alike come to know the limitations of the graduate's ability when he first steps out into factory life, and bides the time for criticism until he can adjust himself to the new conditions, then the last bar will be let down and technical ceramics in the United States will press onward until all will be compelled to welcome it in laboratory and factory. At least, that is what is coming to pass in Illinois at the present time.

RE-ENFORCED CONCRETE AS APPLIED TO POTTERY CONSTRUCTION.

BY

ARTHUR S. WATTS, Victor, N. Y.

In bringing before you the subject above mentioned it is not my idea to discuss the preparation of concrete or the systems of re-enforcing concrete, but to call your attention to the fact that this is to my mind the ideal material for erecting potteries. All woodwork about a clay working plant is thoroughly dry and the fact that for economy's sake the ware must be fired close to these dry buildings makes the fire risk very serious. The insurance companies appreciate this fact, as the rates of insurance indicate. If the manufacturer could know that his plant is proof against fire and could add the amount which he now spends for insurance to his annual profits, the outlook for clay manufacturing industries would brighten immensely. Moreover, wood construction has become so expensive that a brick building can be erected almost as cheaply as a frame building. However, your floors and ceilings must be of wood. Of course steel truss and fire proofing floors could be used, but the delay incident to obtaining steel material and the cost of this form of construction are against its use. In many of our recent pottery fires the loss of models, molds and ware in the process of manufacture has been more serious than the loss of the buildings.

What the potter wants to-day is a form of construction which is in itself fireproof, which can be built without serious delay on account of material and which will not cost far in excess of frame construction. I believe we have this in the new plant of The Locke Insulator Mfg. Co. at Victor, N. Y. The only wood used in the construction is for window frames, which could not be obtained of iron without long delays. The floors are all of re-enforced concrete and are constructed to stand a live load of 200

pounds per square foot, so that any ordinary pottery machine can be located where you please with no fear of overtaxing your floor. The ceilings and roof being of concrete, furnish a solid fastening for any heavy shafting. The floors being supported by columns and not walls, enables you to have as many windows as you wish. The foundations, as shown in the accompanying drawings, are flared at the base, thus furnishing a very substantial fastening, which is also re-enforced with steel bars.

The columns are constructed of bars of twisted steel held in place by steel coils forming a skeleton column one inch less in diameter than the completed column. This skeleton is incased in concrete, making a solid column. The columns are filled at the same time as the surface above, so that column and floor are firmly joined. The walls between the outside columns are not filled when the building is erected, but are put in as curtain walls later. The number of columns can be reduced by using heavier steel bars and making the spans longer without in any way weakening the structure, as the concrete is only used to take the load of compression.

For erecting storage bins for heavy materials, such as clays and spar, I find this form of construction ideal. The plan shows the clay storage bins along the railroad front, which in our case is above the level of the second floor of the plant. This enables us to deliver our materials from the car into the storage bins by gravity. The materials are stored on the second floor of this building. On the first floor are the mixing tubs or ball mills, which are filled from hoppers in the floor above. These hoppers are loaded when convenient and it only requires the pulling of a chain to fill a mill. The columns supporting these storage bins are 12″ in diameter and 10 feet apart. These storage bins are carrying at present 700 to 800 lbs. per square foot of floor surface with no evidence of strain.

Of course, there is an additional expense for steel in such heavy construction, but even with this added I doubt

FIG. 27. General View, showing position of factory with reference to Railroad.

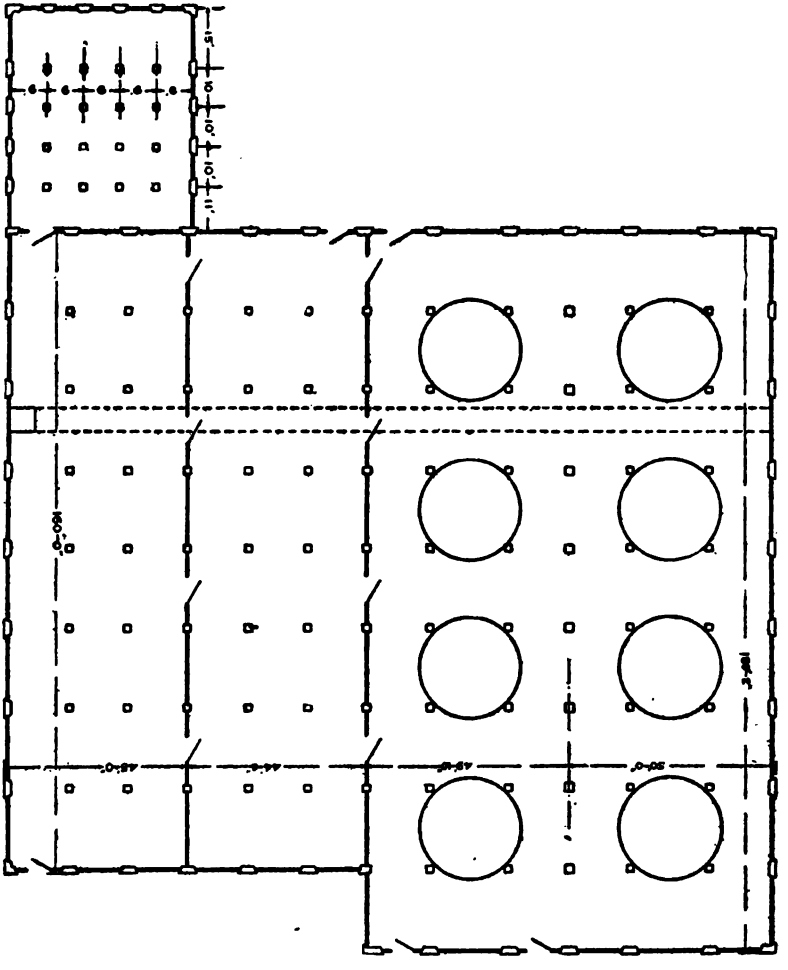


Fig. 30. Ground plan of factory No. 2. Lock Insulator Mfg. Co., Victor, N. Y.

position of the coal bins. I would like to know whether the coal is delivered by gravity into the coal room?

Mr. Watts: Yes, it is. I think I have a drawing of that. There is a detailed drawing showing just the way the reinforcing was done. You see, each of these sections here is a bay, and the concrete is reinforced by a couple of twisted steel bars to take the tension. The concrete, then, only has to take the load of compression. This drawing (indicating) shows the dip of the kiln shed, with the valley in the center. We shall have a steel roof over the lower bay, and the two bays will be used as a great hopper to hold a coal supply. Our factory is located sixteen feet below the level of the railroad, which gives gravity as a means of handling our material. The coal is dropped out of the car into the hopper above the conveyor. It can be accomplished as well when the factory is on a level as when below the railroad. Then along the kiln shed there are my coal chutes. I propose dropping the coal, as nearly as possible, directly over these coal chutes. I first thought to put the coal in a great hopper, but I found the expense would be so great as hardly to be justified. We can get enough coal in these chutes to run 24 hours.

The Chair: The pile is right above the chutes?

Mr. Watts: Yes, sir. In case of pending strike, I would have the area between these chutes filled.

The Chair: What is the size of the chute?

Mr. Watts: Three by three feet-six. The bay here (indicating) has an area of 30 feet wide by 15 feet long for coal storage.

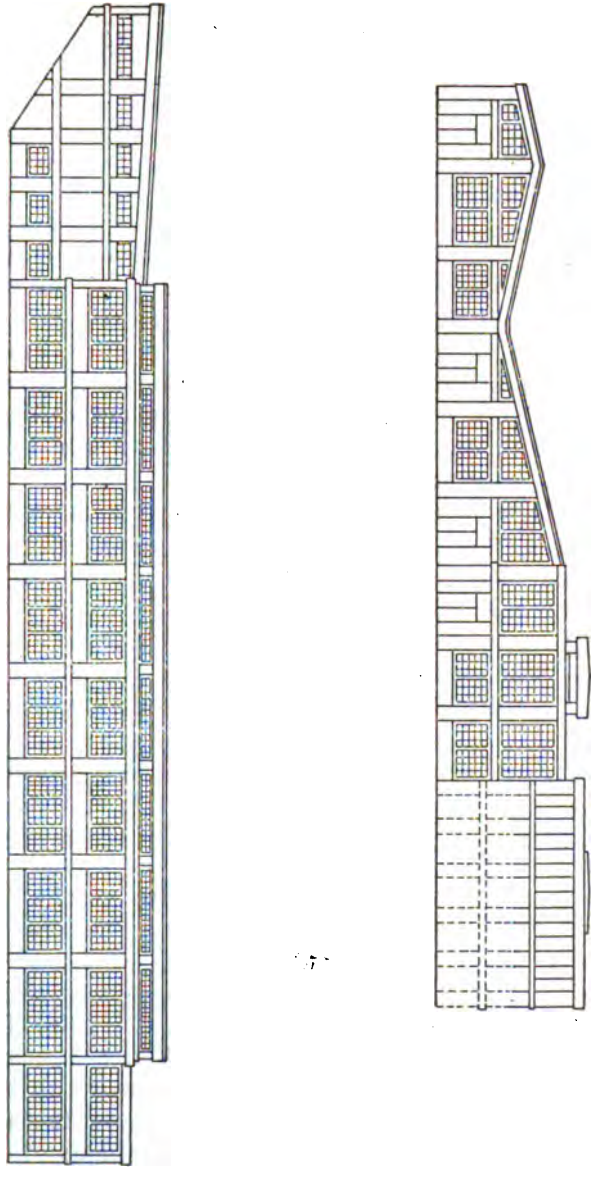


FIG. 34. Exterior view of factory No. 2.

A FEW FACTS CONCERNING THE SO-CALLED ZINC SILICATE CRYSTALS.

BY

FRANK HARWOOD RIDDLE, Columbus, Ohio.

Several articls have appeared in the transactions of this Society and also in technical and trade journals concerning crystalline glazes. The majority of these articles have dealt with crystals formed by mixtures of titanic oxide or the crude rutile and zinc silicate, and to my knowledge, although it has been mentioned as possible, no articles have been published regarding crystalline glazes in which zinc oxide is the only ingredient used to produce the crystallization.

In a few short experiments the writer has endeavored not only to show that it is possible to produce crystals using zinc oxide in the glaze without titanic acid, but also to give a detailed account of the physical treatment both of the preparation and firing of the glazes. The cooling was watched especially, as this is regarded and proved to be one of the most important points in the process of crystallization.

The first step was to make a glaze containing zinc oxide as the only element used as the crystallizing agent, and to make it, if possible, so that it would crystallize under reasonable heat treatment. To accomplish this end experiments were carried out according to the following statements. Crystallization is caused by supersaturation. If zinc is the agent used, it is to be employed in large amounts. Since it is a base and will require an acid, enough of the acid must be present to satisfy the zinc. The glaze is usually regarded as a zinc silicate, hence silica is the acid to be employed. As it is necessary to have zinc oxide and silica both present in large amounts and a high temperature is required to bring about chemical combination, it was evident that fritting would not only lower the

maturing point of the glaze but would also tend to produce the zinc silicate before being put in contact with any other materials.

It is evident that a soft fluxing matrix of some sort is necessary, from which the zinc silicate is allowed to separate out.

The Flux or Matrix.

It is essential that a fritt should be used free from alumina, it being a well known fact that alumina produces viscosity and that viscosity tends to prevent the separation and crystallization of the glaze. Also, there must be sufficient insoluble RO elements and silica present to make the fritt insoluble.

The following fritt was used and called fritt *b* throughout the experiments:

Fritt b.

$$\left.\begin{matrix} 0.25\ K_2O \\ 0.25\ Na_2O \\ 0.50\ CaO \end{matrix}\right\} \begin{matrix} 2.25\ SiO_2 \\ 0.75\ B_2O_3 \end{matrix}$$

Combining weight 254.4.

Batch Mixture.

Potassium nitrate	13.95	parts by	weight
Calcium carbonate	13.81	"	"
Flint	37.29	"	"
Borax	26.38	"	"
Flaky boracic acid	8.53	"	"

Fused to a glass at a bright red heat.

All fritts were made in a 6″ x 8″ high temperature furnace, fired with gas and compressed air. They were placed in Hessian crucibles, fired and held until the mass was fluid. Then the crucibles were removed and the contents poured into water while molten, in order to facilitate the grinding.

The zinc silicate fritt was made according to the formula $Zn\ SiO_3$, by using

Zinc oxide	57.44	parts, by weight
Silica	42.56	" "

This mixture was put in the furnace and heated to as high a heat as could be reached in the furnace. The heat was not sufficient to liquify the mass. For this reason ten per cent. of the calcined fritt *b* was added and a good fusion obtained at about cone 15. The fritt with the addition of the fritt *b* would have the composition:

Fritt a.

0.947 ZnO		
0.0135 K_2O	1.064	SiO_2
0.0135 Na_2O	0.039	B_2O_3
0.026 CaO		

All fritts made were ground in the ball mill until they were fine enough to pass a 100 mesh screen.

Both fritts being made, the next question was to find the proper proportions in which to mix the two. The following series was designed to try out the proper proportion and was called Series I.

Series I.

No. 1,	fritt *a*	.....	25	parts;	fritt *b*	.....	75	parts
" 2,	"	.....	45	"	"	.....	55	"
" 3,	"	.....	55	"	"	.....	45	"
" 4,	"	.....	65	"	"	.....	35	"
" 5,	"	.....	75	"	"	.....	25	"

To all trials for every other as well as this series 0.6 grs. of copper oxide was added for each 100 grs. of glaze. This gave a turquoise blue color to the glaze, which not only made them more agreeable to look at but showed the

crystals to a better advantage than the white would have done. Dextrine was added to the glazes to hold them to the tile.

The body used in all cases was a common, soft, white, dry-press tile body and the glaze was supplied with a camel's hair brush, usually a little thicker in one place than in another part of the tile so as to show the effect of the thickness of the glaze.

In series I, the different glazes were all put on one tile, being put on as close together as possible, and in the order of their numbers, so that from one end of the tile to the other there would be a gradual decrease in fritt *b* and increase in fritt *a*. When the glazes were in a state of fluidity, they tended to run together and thus formed blends in still greater variety.

Heat Treatment of Series I.

The maturing temperature of the glazes was first determined and found to be at cone 02, down flat, with cone 01 tipping or touching.

First burn.

A muffle kiln of about twenty cubic feet capacity was used, natural gas being used as fuel. It took twenty-six hours to obtain the desired temperature. This heat was held about an hour and then the kiln was slowly cooled, requiring 23 hours.

Results.

Trials 1 and 2 were very good turquoise blue glasses, but showed no crystallization.

Trial 3. This trial showed small crystals radiating out from the side of the tile. They were suspended in a perfectly clear glass. The crystals were composed of slender, bar shaped masses, arranged in stellate form and varying in length from one-eighth to one-fourth of an inch and were about one-thirtysecond of an inch wide. The end of

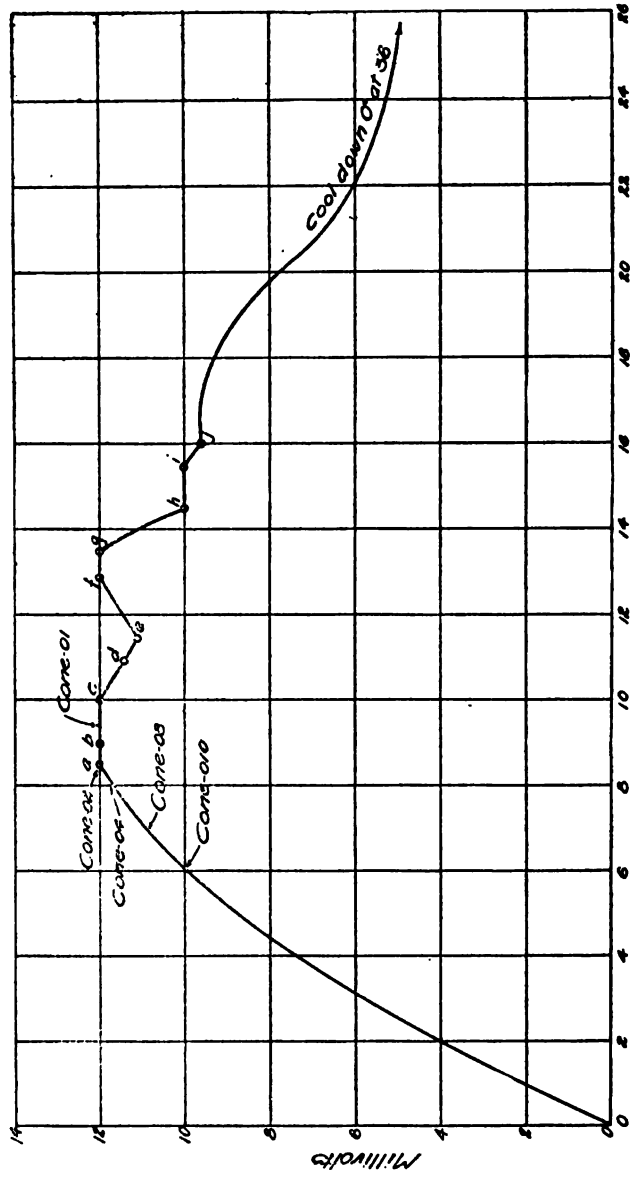


FIG. 35. Heat treatment of zinc silicate glazes, Series I and II.

each bar flattened out to a fan-shaped tuft of about twice the width of the bar.

Trial 4. A mass of small needle-like crystals, making a coarse matt finish, which sparkled in the light and distinctly showed crystalline growth.

Trial 5. A blistered opague mass of a crystalline nature.

Between trials 3 and 4, where the two had run together, small crystals about one-eighth of an inch long were reaching out from No. 4 into the glassy mass of No. 3, forming crystals similar to those described above.

Second burn.

A 10″ x 24″ up-draft muffle kiln was used in this work, fired with a mixture of coal and coke. It required twelve hours to fire the kiln up to the maturing temperature. The heat was held here for a few moments and then rapidly cooled down to cone 010, held for two hours by refiring, and then cooled down in about 10 hours.

The results of the second burn correspond with the results of the first, i. e., crystals occurred in the same numbers, but in the second case were much larger and more clearly defined. This shows that the burning, more especially the cooling, has a strong influence upon the results.

Series II.

The results of the previous series showed that crystals could be made under varying conditions of fire, but the best results were obtained in both cases in mixtures between No. 3 with 55% fritt *a* and 45% fritt *b* and No. 4 with 65% fritt *a* and 35% fritt *b*.

For series II, I took these two as extremes and made cross blends between them so as to get at the best mixtures.

No.	1,	fritt *a*,	55.0	parts;	fritt *b*,	45.0	parts;	CuO,	0.6	part
"	2,	"	57.5	"	"	42.5	"	"	0.6	"
"	3,	"	60.0	"	"	40.0	"	"	0.6	"
"	4,	"	62.5	"	"	37.5	"	"	0.6	"
"	5,	"	65.0	"	"	35.0	"	"	0.6	"

The burning was done by the same method and in the same kiln as the second firing of series I.

Results.

No. 1. This trial showed but very few crystals. Some were bar shaped and all of them were flattened out on the end, forming round and fan shaped extensions and some even opening the fan into a complete circle. Besides the bar shaped crystals, there were a number of small stellate crystals of such fine crystallization as to appear as mere flat circles, with the spokes or radiating needles hardly noticeable. None were larger than one-sixteenth of an inch in diameter.

No. 2. This contained many more of the bar shaped crystals, some being about one-fourth of an inch long and one-sixtyfourth inch wide, and in all cases broadening out at the ends. Sometimes the bars occur alone and again in groups of two, three or more. If more than one, they always take the stellate form. A good many of the small circular crystals were also present.

No. 3. The single fan shaped crystals do not occur, but the trial is completely covered with a net work of bar crystals, all assuming the broader fan shape at the ends. The sides of the tile offer a good starting place for the crystals, so that there is a border of them completely around the piece.

No. 4. The crystals are of similar character and size as in 3, but much thicker. There is also a thicker border around the edge, showing that the addition of more flux *a* tends to be detrimental.

No. 5. The border of crystals around the edge is very thick. The majority of the crystals are larger, silkier and more symmetrically formed, some of the bars being one-half inch long and one-sixteenth inch wide.

Taking the series as a whole, the best results for proper saturation are obtained in No. 3. No. 5 contains crystals somewhat more handsome, but shows by the heavy

matt border formed that there is too much zinc silicate present.

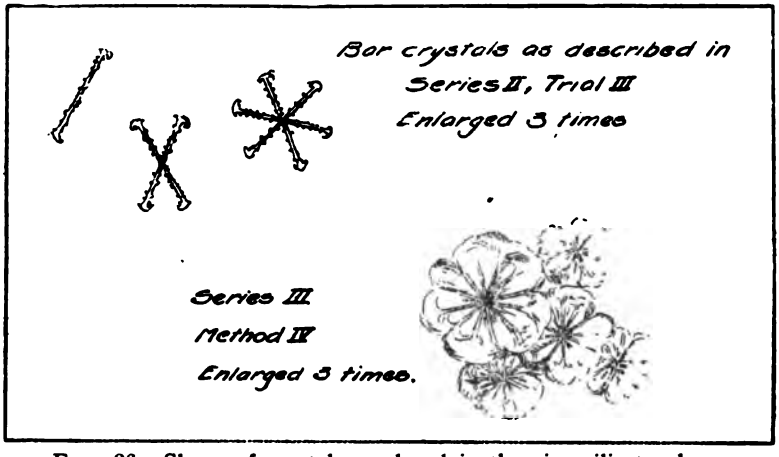


FIG. 36. Shape of crystals produced in the zinc silicate glazes.

Series III.

In this series, the best appearing glaze from series II, No. 3, was used as the glaze. A time temperature treatment was given it, not only by using cones, but also employing a pyrometer. The maturing temperature was reached and then the kiln was cooled in two different ways, noting the effect of each way.

The trial consist of

Fritt *a*	60.0 parts
Fritt *b*	40.0 parts
Cupric oxide	0.6 part

This would give it the chemical formula,

$$\left.\begin{array}{l} 0.7000\ ZnO \\ 0.0750\ K_2O \\ 0.0750\ Na_2O \\ 0.1500\ CaO \end{array}\right\} \begin{array}{l} \\ 1.375\ SiO_2 \\ 0.225\ B_2O_3 \\ \end{array}$$

The CuO equivalent was 0.0145.

A few of these trials were set in the kiln in luted saggers along with some other trials which I will mention below. The rest of the trials, ten in all, were placed in such a position in the kiln that they could be drawn out at will. This, of course, required that they be fired open and hence not to the best advantage.

The Burning.

The burning proceeded according to the time- temperature curve, fig. 37.

As shown, the kiln was heated up as fast as practical to cone 02, well down. This corresponded to 12 millivolts of the millivoltmeter. Trials were drawn at different stages from here on, being lettered alphabetically in the order they were drawn.

Trial a was drawn as soon as cone 02 went down. It was slightly immature, all the gas not having been given off. The heat was held at 12 milli-volts and in half an hour trial b was drawn, which still showed the glaze to be immature. At the end of another hour, trial c was drawn, and proved to be a good mature glaze. The heat was then gradually lowered to 11.5 milli-volts, requiring one hour to do it. Trial d was drawn here. It showed crystallization to have set in. About half of the surface was covered with a mass of very small needle-like crystals, not more than one-thirtysecond of an inch long, and of just visible thickness. The total mass of crystals gave the glaze a matt finish.

The kiln continued to cool for half an hour, and dropped to 11 milli-volts. Trial e was drawn here, and showed the matt effect to be increasing, i. e., the crystals were increasing in number but not in size.

The two first burns mentioned with series I showed that a slow gradual burn made fine crystals, and that a burn to maturity and then a sudden drop in temperature to cone 05, withholding the temperature here, produced larger crystals. The draw trials d and e showed that slow cooling was producing fine crystals. As large ones were

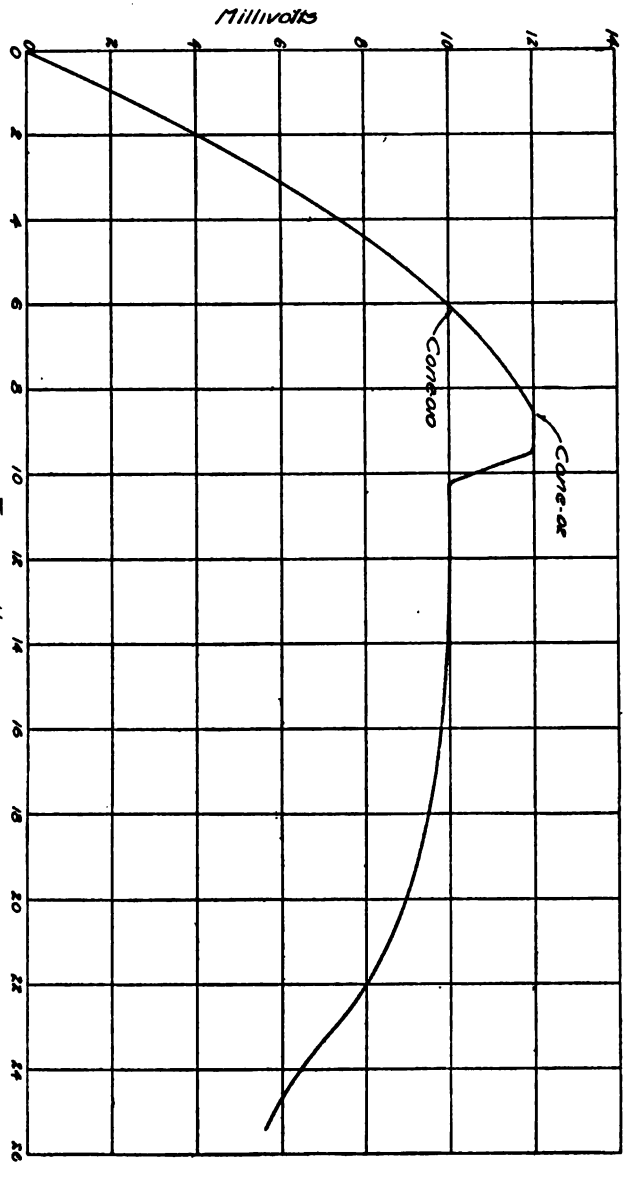


Fig. 37. Burning and cooling curve employed in fusing the zinc silicate glazes, Series III.

desired, the kiln was heated up again to 12 millivolts and trial f drawn to see whether the crystals had re-dissolved. They had not, so the temperature was held forty-five minutes and then trial g was drawn and showed the glaze to be clear.

As the glaze was clear, the damper was drawn up and the firebox opened, allowing sufficient excess of air to pass through the kiln to cool it down to 10 millivolts in forty-five minutes. During this cooling the fire was kept sufficiently alive so as to stop the cooling at will. When 10 millivolts (corresponding to cone 010) was reached, the door and damper of the kiln were replaced in their proper positions, and the temperature held.

Trial h was drawn as soon as 10 millivolts was reached. Crystallization had set in. It was of the bar-shaped type, some crystals being one-fourth of an inch long, but not very wide. Very few of the small matt glaze crystals were noticeable.

After holding the temperature at 10 millivolts for one hour, trial i was drawn. The number of crystals present was not only increasing but the width of those already formed was about doubled. The little fan shaped forms at the end of the bars were also appearing.

In thirty minutes more the kiln heat dropped one-half millivolt. The crystals had not grown to any noticeable degree. This was the last piece drawn, trial j. The kiln cooled slowly from here down. When cool, trial k was drawn, but showed no improvement over i. A table would show the trials as follows:

Trials.	Cone.	Millivolts.	Treatment.	Results.
a	02 touch.	12	Drawn at once...	Immature, bubbled.
b	02 down.	12	Held 30 min....	Slightly immature.
c	01 tipped	12	" 90 "	Matured.
d	04 down.	11.5	Cooled 60 min...	Very fine matt crystals.
e	08 "	11	" 90 " ...	" " " "
f	02 "	12	Reheated...	Nearly dissolved.
g	02 "	12	Held 45 min....	Redissolved.
	The glaze is redissolved and re-cooled.			
h	010 down	10	Cooled 45 min...	Bar crystals ¼ in. long.
i	010 "	10	Held 60 min.....	Broader, greater number.
j	011 "	9.5	Cooled 30 min...	Similar to i.
k	0	9	Cooled 20 hours..	" "

This burn, as mentioned above, included some other trials which were placed in the luted saggers. These were glazes of the same chemical composition as the glazes employed before, but prepared by different methods.

Glaze composition:

$$\left.\begin{matrix} 0.700\ ZnO \\ 0.075\ K_2O \\ 0.075\ Na_2O \\ 0.150\ CaO \end{matrix}\right\} \begin{matrix} \\ 1.375\ SiO_2 \\ 0.225\ B_2O_3 \\ \\ \end{matrix}$$

$$.0145\ CuO$$

Method I. The regular method used in all previous trials was by fritting the zinc silicate into a glass by the addition of 10% fritt *b* and using 60% of this mixture and 40% more of fritt *b* as the final glaze. We repeat here formulæ of the fritts *a* and *b*:

Composition of fritt *a*:

0.947 ZnO	
0.013 K_2O	1.064 SiO_2
0.013 Na_2O	0.039 B_2O_3
0.026 CaO	

.712 equivalents of this fritt were required.

Composition of fritt *b*:

0.25 K_2O	2.25 SiO_2
0.25 Na_2O	0.75 B_2O_3
0.50 CaO	

.274 equivalents were required of this fritt.
.0145 equivalent CuO was added.

Batch weight:

Fritt *a*	60.0 parts
Fritt *b*	40.0 parts
Cupric oxide	0.6 part

Method II. Here the zinc oxide and silica of the zinc silicate were added raw, and the 10% of fritt *b* added as a fritt along with the 40% of the above batch weight. This gives the batch weight:

Fritt *b*	45.45 parts
Zinc oxide	31.32 parts
Cupric oxide	0.60 part

Method III. In this case the lime of the fritt *b* was replaced by the equivalent weight of zinc oxide and then the lime, remaining zinc oxide and silica added raw. The composition becomes then:

Fritt *c*:

$$\left.\begin{matrix} 0.25\ Na_2O \\ 0.25\ K_2O \\ 0.50\ ZnO \end{matrix}\right\} \begin{matrix} 2.25\ SiO_2 \\ 0.75\ B_2O_3 \end{matrix}$$

Raw materials added:

$$\left.\begin{matrix} 0.7867\ ZnO \\ 0.2140\ CaO \end{matrix}\right\} 1.0\ SiO_2$$

0.7 equivalents were required.

Batch weight:

Fritt *c*	34.8 parts
Raw addition	65.2 parts
Cupric oxide	0.6 part

Method IV. All of the materials were fritted together. The formula is:

$$\left.\begin{matrix} 6.700\ ZnO \\ 0.075\ Na_2O \\ 0.075\ K_2O \\ 0.150\ CaO \end{matrix}\right\} \begin{matrix} 1.375\ SiO_2 \\ .225\ B_2O_3 \end{matrix}$$

$$.0145\ CuO$$

Results of the Four Methods of Treating the Glaze.

Method I. The crystals described above were obtained. However, the crystals formed on the trials in the saggers were much better, being larger and more symmetrical. In many cases, the bars assumed perfect stellate forms, the ends of the bars forming the fan shaped crystals, the bars being so close together that the broadened ends meet, forming a complete circle.

Methods II and III. These were both underfired owing to the presence of the materials added raw. However, in some places where the mass had been slightly fused, crystals were forming showing that more heat was all that was required to bring the desired results.

Method IV. These trials showed more of a tendency to crystallize than the trials of method I. In many cases the crystals were so numerous that a coarse but very beautiful silky matt was formed, while again the stellate crystals, some ½ inch in diameter, occurred in groups.

Conclusions Drawn from the Above Results.

Preparation of the glaze. The results of the four methods used in compounding the glaze show that the zinc silicate will crystallize out whether added raw, fritted in part or in total. It seems to work best when fritted in total. This would seem to show that the more homogenous the glaze is, the more perfectly the crystals will separate out.

The firing. Crystals were formed in all the methods of procedure, but the best results were obtained when the glaze was brought up to maturity and then cooled down as rapidly as possible to the best crystallizing point, cone 010, and held here as long as possible and then gradually cooled down. This quick cooling would also prevent the glaze from running off from vertical surfaces.

The reason for cooling quickly to cone 010 is to prevent the small matt crystals from forming. The exact cause for this is rather hard to explain. It is possible that in cooling slowly, the crystals start to form all over the glaze and so in growing soon come in contact with one another, become interlocked and irregular and so form a matt surface. In cooling rapidly, the tendency to crystallize out is not so strong, therefore only a few crystals start to grow. It is much easier for the remaining crystallizing material to grow on to that already started, than to start new formations, hence the large crystals. If there were only a few started, evidently they would find plenty of

room to grow. They can also draw material from all sides and so form symmetrical shapes.

Another possible explanation is that as the glaze begins to solidify, it is in a more diluted condition, so to speak, and therefore not capable of forming as large crystals as when nearer saturation. A proper degree of saturation is thus indicated at the temperature at which crystals separate out most favorably. As the glaze cools more and more, it might be said to become more and more saturated, so that the crystals will grow larger and more rapidly. Now, if the so-called diluted conditions are passed over rapidly, there is little chance for the small crystals to form and therefore more material becomes available for crystallization when the proper temperature is reached. The case is analogous to the crystallization of salts, like alum, from dilute and more concentrated aqueous solutions.

To make the best crystals, then, the following methods would be the best of those tried.

Fritt the glaze in total, using the following ingredients:

Zinc oxide	27.389	parts by	weight
Potassium nitrate	7.382	"	"
Borax	13.770	"	"
Whiting	7.200	"	"
Boric acid (flaky)	4.466	"	"
Cupric oxide	0.600	"	"
Flint	39.693	"	"
	100.600		

Grind as fine as possible and apply to the surface desired to be glazed, using dextrine to make the glaze stick.

The best kiln treatment would be according to the temperature curve of fig. 37. Oxidizing conditions must prevail throughout. In the experiments coal, coke and natural gas were used as fuel, with equally good results.

The coloring oxide used has no marked effect on the crystals. Copper, manganese and iron were used with

equally good results. The crystals do not take up the color, so in all cases they appear white against a colored back-ground.

An interesting thing is the production of a turquoise blue by the use of copper, caused by the absence of lead and the presence of zinc. It is not essential, however, that the zinc be present for the production of this color, neither does the absence of alumina affect the color. The writer has made turquoise blue from raw copper oxide in glazes, free from lead and zinc, and containing 0.3 equivalent of alumina.

Although not pertaining to the subject, a very good aventurine glaze can be made by supersaturating fritt *b* with some coloring oxide and firing it to maturity. Ferric oxide works especially well, giving a rich red color.

These experiments have been short, but have proved that crystals can be made without the use of any other crystallizing material than zinc. However, the investigations are far from complete and I trust that some one will use the results of this work and proceed further along this line of research.

THE MANUFACTURE OF REFRACTORY MATERIALS FOR GLASS WORKS CONSTRUCTION.

BY

ROY H. MINTON, Zanesville, Ohio.

The manufacture of glass into its many products is, to-day, one of the many important branches of the ceramic industry. Like ceramics itself, the glass indutsry is in its youth, as far as realizing the wonderful scope it is capable of covering is concerned, although in itself it is probably the oldest of these related industries. It is fast taking the place of other materials in the manufacture of many articles where heretofore its use had not been dreamed of.

The manufacture of sanitary articles from glass presents a large field for future development. In Germany there is now made a kind of glass brick claimed to be devitrified before the brick is manufactured, the devitrification taking place partly in the melting chamber and partly in the refining space of the glass tank. It is claimed that these brick excel the finest Swedish granite in hardness and wearing qualities. The bricks, which are only one inch thick, stand enormous pressure and are absolutely acid proof.

The ancients did many wonderful things with large glass articles, but we bid fair to outdo them. With glass brick and wire glass for houses, we will make glass belt courses, door and window sills and caps, mouldings, cornices and pillars.

We are hardly advanced enough to make glass bath tubs that will withstand the extreme and sudden temperatures, but no doubt the time will come. We might also mention that there are now being manufactured large conduits, telegraph poles, refining vats, water troughs, etc., and with the wonderful growth in the mechanical facilities for making and handling glass articles, we may expect their manufacture on such a scale as we have not thought possible before.

Divisions of the Glass Industry.

The glass industry is divided principally into plate glass, window glass,bottle and flint glass, opalescent and ribbed glass, with wire glass and prism glass as important new factors.

There are two principal methods used for melting the glass, by direct and regenerative tank systems and by pot furnaces, each using gas regenerators or gas producers. For opalescent and flint glass the pot furnace is mostly used, although small tanks are used for flint bottle glass. The opalescent and flint glass are of a better grade than window glass, and glass men usually contend that the pot makes better glass than the tank, but the time has come when window glass makers must either use a tank or quit the business, from the mere standpoint of economy alone. In saving the cost of pots, economy of fuel and repairs, the tank almost pays for itself the first year. Just recently there came to our notice a case where one firm had burnt out sixty-three pots in less than seven weeks' run, which would indicate that there is still room for improvement in the manufacture of glass pots, or the adoption of some improved processes in melting the glass materials.

History of the Glass Industry.

The tank business, like everything else, has been a process of evolution, and is still in process of improvement. There are numbers of tanks in use today that produce as good window glass as can be made in pots, but for the highest grades of glass the tank is not so much in favor.

Previous to the window glass machine, the continuous tank was one of the epoch-making inventions which has given a mighty impetus to the glass industry during the last quarter of a century. The tank was first used in England and followed by Germany, but for some time it was looked upon with suspicion in the United States. The first practical, successful tank was operated at Jeannette,

Pa., in 1888, by the Chambers-McKee Glass Co., although some experimental work was done before this time at other places.

The United States census report for 1890 contains very little concerning glass tanks, but between 1890 and 1904 the number of installations was remarkable, and although we were slow in taking up the tank system, after its adoption great numbers of these furnaces were built. We use the largest as well as the smallest tanks and we adopt them to more branches of the industry than Europeans dare do. Bohemia leads the world in glass colors, because, it is asserted, her glass masters melt their finest colors in small pots, so that the metal can be worked out in its prime condition. In this country the small day tank is utilized in making cadmium yellow — the most sensitive of all glass colors.

The advantages of the continuous tank may be briefly stated to be:

1st. Increased capacity of production.

2nd. Economy in labor.

3rd. Durability, owing to uniform temperature.

4th. Regularity and improved quality of glass, as the metal is drawn from a constant, uniform level.

Manufacture of the Refractory Materials.

Long experience has shown wherein lie the strong points of a tank and each succeeding year finds some improvements. To Mr. C. Edwards Holden, the founder of the Mineral City Fire Clay Works, and to his superintendent, Col. R. R. Morrison, is due the credit of building the first window glass furnace west of the Alleghany mountains, at the present passenger depot site of the Erie Ry. at Kent, Ohio, and they have built a large percentage of the window and flint glass tanks and furnaces erected in recent years.

Their construction, together with the blocks, fire brick and fire clay used, has a wide reputation, many glass pot and tank block manufacturers depending upon the Min-

eral Point flint clay for the excellent results in glass manufacture. Perhaps a few notes on the method of manufacture of glass tank blocks would not be without interest.

Clay Formation.

The flint clay used seems to be a part of a very unique and exceptional formation, being a part of the Lower Kittanning formation of clays and coals, and lying at varying distances below what is called No. 5 coal. All the clays in this section show strong evidence of water formation, or deposition, as though they were deposited in a whirl pool. The flint clay occurs in irregular pockets, ranging in thickness from four or five feet down to nothing, sometimes suddenly running out and then reappearing unexpectedly.

In color the clay is a shade of gray, tending toward brown rather than blue, very hard and flinty, breaking like glass, and showing a conchoidal fracture with smooth surface.

This clay is shipped in large quantities to glass pot and tank block makers, and forms the body of these products, being used with German pot clay as the bonding agent. So far no American clay seems to have been found equal to the German for the bond, although in recent experiments we have found that the German clay forms the weak point, as it melts at about cone 25, while in a ten-hour test at cone 30 and 32 the flint clay was not touched and endeavors are now being made to find a better bond clay. The Missouri pot clay and the best Pennsylvania flint clays have been tested in actual practice with poor results.

The flint clay is won by mining, and immediately removed to the screening house, where it is screened and hand-picked by girls who break any doubtful lumps into pieces with small hammers, and carefully remove any impure clay containing segregations of silica, or any iron, which usually occurs in the form of the carbonate. The

picked clay is then re-examined by an expert, and stored ready for the grinding.

The grog used in the clay mix is the calcined flint clay, which is hand picked before and after being burned in a down-draft round kiln. This careful treatment insures an excellent grade of material to start with.

Requirements of Tank Blocks.

The main essentials of a good tank block are high refractoriness, resistance to the fluxing action of lime, salt-cake, etc., used in making the glass, strong resistance to the wearing action of the moving glass and non-conductivity.

Time and experience have evolved mixtures of the flint clay, calcined clay or grog, and German clay, which seem to produce the best results.

The different ingredients of the mixture are measured out and ground together in a dry pan and then through six sets of French buhrs and over vibratory screens to the desired sizes, which are determined by the use to which the clay or mixture is to be put, as the size of the grain has a great deal to do with the behavior of the clay product under different conditions. Extreme fineness of grain will often cause fluxing at lower temperatures than coarser grain, especially in silicious mixtures, if the matrix or bonding clay is fine grained. Again coarse grains insure greater resistance to heat, but decrease the resistance to friction or wearing action. Hence quite a problem is presented in determining what mixtures and what degrees of fineness of the various clays entering the mixture are most suited to the use for which the product is intended. This can only be accomplished by experience and intelligent experimenting. The grog used here is ground by buhrs and is invariably round in form and very smooth. Although enough experiments have not been carried out to fully prove the statement, it has been noticed in practice that different sizes of grog used show about the same shrinkage and produce the same porosity of body, if it is

thoroughly worked and homogeneous in structure. At first thought, one is inclined to think that there is or should be a marked difference, but there seems no good ground for believing so, for with equal percentages the fineness of grain ought not to have any influence so long as the body is thoroughly uniform. In a body with a given percentage of grog there is just so much solid matter, which has no further shrinkage, and the total shrinkage in volume is practically constant, hence the linear measurements must be the same. These statements are based on the use of grog in practice, where the grog consists of every size from a given mesh down, but whether the same conclusions will be found from the use of grog graded between certain sizes has not been demonstrated. The blocks vary in size from 24″ x 15″ x 8″ or smaller, up to 120″ x 30″ x 18″ as a maximum.

The tank block must be well burned to reduce shrinkage, which is a vital point in tank service; it must be dense to resist fluxing and wearing action and not so dense as to induce cracking or checking. It must be able to stand high temperatures and be as much of a non-conductor as possible. These requirements of a good block seem somewhat conflicting and are hard to meet and require first of all exceptional material and then the most careful manufacture.

In making pots the clay must withstand changes of temperature, fluxing action and high temperature and still be as good a conductor as possible. This involves another problem and such different conditions required with the same material must be met by the manner of treatment and method of manufacture.

Tempering the Materials.

After grinding, the clay mixture is tempered in wet pans to a certain consistency which can be learned only from experience with the particular clays used. The tempering process is one of the most important in the course of the manufacture. If the clay is not sufficiently tem-

pered, the block shows it by cracking or by excessive shrinkage. In the manufacture of this class of materials every part of the process is dependent upon every other part, for care in the latter stages will not remedy carelessness in the earlier part of the process. After the clay is tempered, it is packed in bins and allowed to age, the longer it cures the better it will work. When worked direct from the pans, it works short and is very liable to give trouble in the drying stage.

Just before molding into blocks, the clay is run through a pug mill and comes out in the shape af sausages, about six inches long and three inches thick. All the blocks are molded by hand in wooden frames, and proficiency is acquired by practice, the finished blocks of the different workmen showing great differences, the blocks molded by inexperienced men giving trouble in drying from cracking or warping. The better molded blocks also show a greater density.

Molding the Blocks.

The molds simply form the four walls of the block, and for each block the mold is lined with water-soaked cloths, the whole block resting on another cloth. The clay sausages are thrown into the mold one at a time, and pounded firmly with the hand, and clawed and scratched with the fingers to insure density, homogeneity, freedom from laminations, and most important, absence of any air holes or cracks, care being used to prevent any hardened chunks of clay or any sticks or rubbish to become mixed with the clay. Seemingly very small factors influence the quality of the ware resulting from different ways of molding. It is sometimes the custom of new molders to constantly wet their hands while molding, and this almost always produces a bad block, which usually cracks before drying. If the block cracks while it is green it can be safely patched, but if it gets past this stage it is beyond redemption and is reground.

Some tank block manufacturers use compressed air

and hand tampers for working the clay into the molds for making blocks, but their products do not seem to stand up with the old method of working in the clay by hand. The tamped blacks seem to have great density, but somehow do not have the same texture.

Drying Process.

The drying of the blocks requires much care. As soon as the block is molded, the frame is removed, and the block covered on top with a cloth. When the block is leather dry it is turned up on its side in order to allow the bottom to dry. The drying is done on floors which are heated from above by steam pipes. This gives a more uniform temperature than if the pipes were beneath the floor and even by this method in cases where the pipes are lower than usual, the blocks must be kept well covered on top to prevent unequal and rapid drying and resultant cracking. When the blocks are placed on a floor over a large steam pipe or over a boiler, or near a stack, great trouble is experienced from bad cracking, the blocks often breaking along their full length. Where the floors vibrate from the machinery the blocks are hard to dry successfully.

After the drying, the blocks are dressed to a given size, the angles being made true right angles and the faces being also trued up. Most of this work is done by hand with two-edged axes and chisels and finally finished to the square and straight edge with a rubbing block of the same material. Some experiments have been made with a pneumatic cutting machine for the rough cutting, but so far no appliance has been found to give the good results of hand dressing.

The dressing usually brings out the defects in the molding, all air cracks showing up. The time for drying depends upon the weather, varying from two to six weeks.

Burning Process.

After dressing, the blocks are burned to about cone 12 or 13. The setting requires the same general careful handling, as the blocks are very tender when dry, and in case of extremely large blocks it is necessary to take them into the kiln when only partially dried and finish the drying there. Round down-draft kilns are used. A ring of fire bricks is placed around the outer part of the kiln to protect the blocks from the flames. The burning must be conducted in the most careful manner, for with large blocks of this density it is an easy manner to ruin the kiln at the start. The water smoking requires from one week to ten days or more, depending upon the dryness of the blocks and the weather. Usually the fire is begun with wood in about four fire holes, and in a day or two more the fire is changed to coke and gradually to coal. When the steam is all out, the fire is raised rapidly and finished at cone 12 in from two to three days.

Grades of Block.

Two grades of blocks are used in the tanks, one known as the common or furnace grade, and the other as the flux-line grade. The furnace grade blocks are used in the bottom and part way up the sides where the glass is very viscous, or in a chilled condition and the fluxing action is not very great, the blocks being thus protected from the intense heat in the upper part of the tank. The flux line blocks define themselves; they are used in that portion of the tank where the glass is in the most fluid condition, and hence most active as to its action on the blocks. The fluxing part or melted glass zone is taken as about 12 inches, but the flux line blocks are usually 36 inches in height, or three courses of 12 inches each. These blocks cannot be made too well. Any little crack or air hole in the block invites immediate attack from the glass and the block soon honey-combs or eats out. Such foreign matter

as sticks, or threads from the molding cloths, has the same effect. Trouble is often experienced with some blocks causing what is known as stoning, chunks or spalls of the block falling off into the glass. Often this is the fault of the block, sometimes it is caused by the glass mix being too alkaline, by change of materials, usually too much soda and too little lime, and sometimes it is caused by irregular or too rapid heating, this being one of the important considerations in the process of building a tank and getting it into running order. The tank acts similarly to a new kiln, where the bands must be loosened when first heating up, and gradually tightened, just so in heating up a tank, the stays must be loosened as the expansion demands, and care must be exercised in looking to the expansion of the different parts. When it is remembered that a tank must undergo a continuous white hot heat for nine months, while holding a constantly moving mass of strong fluxing material, often weighing as much as four or five hundred tons, one has some realization of the great test to which such clay materials are put in practice.

It is not the intention to go into details concerning the building of glass tanks; suffice it to say that they are constructed with three chambers, the melting or charging chamber, the refining chamber and the working chamber. The chambers are built proportionately to each other, the size depending upon the capacity of the tank, usually so many tons, and this tonnage is usually reckoned from whether it is a 12, 24, 36 or 48 blower tank, the 60 blower size being the maximum. Tanks as large as 90 feet x 26 feet are in operation. With these chambers, or the tank proper, are the regenerators and also the producers if coal is used. And the idea suggests itself here, why not attach regular furnace stokers directly to the tank? The writer knows of no instance where this principle has been used, but there seems to be no reason why it should not be practicable, for a stoker makes perfect combustion, produces high temperatures and coal is a cheaper fuel than gas at 5 cents per 1,000 cubic feet.

The two different kinds of window glass tanks, blower and blow-over, differ from each other in several points and it is impossible to give an adequate description of them without detailed drawings, which may be fully given in some future paper.

Three principal points in the mechanical structure of a tank are: To build in such a manner as to have a current of air coming in contact with all exterior parts of the tank, especially bottom and crowns; to have it well stayed and especially to make proper allowance for expansion when heating up for melting, a 60 foot tank requiring more than 12″ allowance in its length.

The subject of chemical composition and physical conditions of the clay mixture in relation to high temperatures, fluxing action, wearing quality and conductivity, presents a most interesting field for investigation, and one in which comparatively little work has been done.

With these introductory notes we hope in the not distant future to be able to furnish some interesting data as the results of experiments strictly along the line of chemical and physical conditions governing the manufacture of high grade fire clay products, especially for use at high temperatures, combined with strong fluxing action and great friction under heavy pressure, as adapted to the different classes of requirements in the glass industry.

[redacted] MAGNESIA.

X

[redacted] San Francisco, Cal.

[redacted] magnesia which are described [redacted] time to time as opportunity [redacted] therefore handled in a fragmentary [redacted] experiments dictated. Only those results [redacted] when repeated are given, to avoid [redacted] to the reader.

[redacted] experiments were made with a clay taken [redacted] Jersey. This clay is dark in color, [redacted] plastic when worked up with water. [redacted] soluble salts on the surface after drying. [redacted] was 6.3 per cent. of the dry length. [redacted] buff, when burned to cone 5. Its drying [redacted] was 12 per cent. of the dry length. At cone 5 [redacted] vitrified, and absorbs but a small percentage [redacted] Tensile strength of thoroughly dried samples [redacted] per square inch cross section. This clay was [redacted] When made up for a terra cotta body it [redacted] burning to such an extent as to make [redacted] When sprayed on a regular terra cotta body [redacted] quite porous at cone 5 or 6 this clay would be more porous and less vitreous than when burned [redacted]

[redacted] this clay is supposed to be as follows:

	Percents.
[redacted]	52.20
[redacted]	28.40
[redacted]	2.30
[redacted]	11.00
[redacted]	0.40
[redacted]	1.00
[redacted]	1.80
[redacted]	0.50
[redacted]	1.50

The following experiments were made up, sprayed on the standard body and placed in the same kiln to get comparative results for the same cone 5 heat. All were put through the 120 mesh sieve.

(1) Clay 87%
MnO_2 ..... 3%
down to smaller percentages.

When 3% MnO_2 was added, the clay showed a change toward vitrification greater than when sprayed on with no MnO_2. The additions up to 3% showed but little effect or vitrification.

(2) Any increase of china clay or flint increased the porosity.

(3) Clay 91%
Ferric oxide 9%

This percentage of iron increased vitrification. When exposed to flame, would fuse.

(4) Clay 97%
Magnesium carbonate 3%
No perceptible change in the clay.

(5) Clay 95%
Magnesium carbonate 5%
Perceptible change toward vitrification.

(6) Clay 90%
Magnesium carbonate 10%
Vitrified.

(7) Clay 85%
Magnesium carbonate 15%
Vitrified.

(8) Clay 80%
Magnesium carbonate 20%
Slightly porous.

(9) Clay 90%
Feldspar ..... 10%.
Slightly porous.

(10) Clay 80%
Feldspar 20%
Close to vitrification.

(11) Clay 70%
Feldspar 30%
Vitrified.

(12) Clay 60%
Feldspar 40%
Good vitreous surface.

A number of trials were next sprayed with the No. 7 mixture and placed in an updraft muffle kiln which gave variable temperatures from top to bottom and from sides to center. Side by side of these trials were placed the Seger cones. When unloading the kiln, the center cone block showed cone No. 2 down and cone No. 3 bent and the rest standing. Outside (2 ft. from outside,) showed cone 5 down and cone 6 bent. The trials placed where cone 2 was down were vitrified and where cone 5 was down, a little more thoroughly vitrified.

Another set of trials using No. 12 mixtures were placed side by side with those of the No. 7 mixture in the same kiln, which was burned again under the same kiln conditions as before, viz., cone No. 2 down in center and cone 5 down 18 inches from the side of muffle wall. The No. 7 trials showed up as before. The trials bearing the No. 12 mixture where cone No. 2 went down were vitrified. Those where cone No. 5 went down were fused to melting, showing the body, semi-transparent, crude, checked like a glaze.

With a type of muffle kiln which gives an uneven temperature it is difficult to hold a color uniformly on terra cotta from the bottom to the top benches. These kilns were afterwards remodeled, thus securing more even heats.

With this uneven heating, a glaze sensitive to such heating will vary in color and fusibility, thus destroying its usefulness. Where the glaze has fused too much and soaked into the body from excessive or prolonged heat, the

color is volatilized to where there has not been sufficient heat to mature the glaze. If the kiln conditions remain unchanged, one must try and avoid extremes and to secure as uniform a color as possible.

Those glazes which would permit the introduction of magnesia without any perceptible bad effect from lack of fusion or change of colors were in this way enabled to stand a wider range of temperature change than before.

Referring back to the experiments made on the New Jersey clays brings to mind another series of experiments which lead up to the following, taking this clay, feldspar, magnesium carbonate, magnesium sulphate, ferric hydroxide, ferric oxide, flint, and potassium nitrate for materials to draw from. The formula would approximate:

$$A \quad \left.\begin{matrix} 0.20\ MgO \\ 0.23\ K_2O \end{matrix}\right\} \quad \left.\begin{matrix} 1.00\ Al_2O_3 \\ 0.20\ Fe_2O_3 \end{matrix}\right\} \quad 4.9\ SiO_2$$

This matures at cone 01 and holds color even to cone 3. At cone 4 it tends to become brown in color. At the former temperature it is a fair red color.

B. Another experiment substituting Florida kaolin in place of the New Jersey clay and burned to cone 02 was not quite vitrified. The red tended to a browner shade, but was still quite red.

C. The magnesium carbonate was increased to .4 equivalents and was much softer and porous than that of A, though it even had a much higher temperature. The iron would also be marked and would show a light brown. It was, however, much more off color when kaolin was used than the New Jersey clay.

D. Another experiment similar to *B* with the $MgCO_3$ left out resulted in a more absorbent sample than that of *B,* but with a better red color and not as soft as *C.* These were placed close together in the same kiln to get comparative results.

Other experiments using equivalents of magnesia and lime seemed to show as far as the experiments extended

that both magnesia and lime would mask iron, but lime would do this to a greater extent.

Taking a formula for a pink from Seger and substituting the equivalent of magnesia for the lime, the calcined mass is more of a purple-red instead of a pinkish red. Adding this to a glaze with lime and there is still a pink red. Using all $MgCO_3$, the purple-red is shown. Decreasing boric acid and using magnesium carbonate with just a little lime, we obtained a matt glaze. Boric acid being quite volatile, the magnesia seems to hold it and keeps the color from volatizing.

Where the color is not so good for a pink it might be of use in varying these shades where lime could not be used so well.

Other series of experiments with glazes part of which were fritted, containing flint, borax, tin oxide, soda, porcelain mixture, similar to Seger's, and from 5 to 8% magnesium carbonate were made. With this type of glaze $MgCO_3$ seemed to check the fluidity too much; it also allowed the glaze to adhere better to the body and to permit of a more even distribution of color.

In a general way the color variation may not be apparent by comparing a few small samples. The same color an the same body when made in large pieces as in terra cotta and laid down on the fitting floor, may show quite a color range. A modern constructed kiln and proper firing helps a good working glaze to a place of merit. It is not claimed here that one chemical ingredient of a glaze will be a panacea for all these troubles, but used judiciously with other factors carefully considered, it does not seem to serve at least as a check on the troubles mentioned before.

EFFLORESCENCE OF BRICK.

BY

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During the reign of Napoleon III of France, while a large part of Paris was being rebuilt, the walls of the new buildings became coated with unsightly splotches of a white crystalline substance known as efflorescence, or whitewash. The cause and cure of the phenomena so baffled the scientists of that time that the emperor offered a reward of 100,000 dollars to any one who would discover a means of preventing its occurrence. Many of the prominent scientists of Europe at once investigated the problem, but beyond determining the composition of the efflorescence little was accomplished. (Brick, vol. VI, p. 195.) In our own country the first published notice of efflorescence appeared about the year 1882, at which time there was an unusual amount of it on buildings both here and abroad. It appeared not only on buildings under construction, but also on those never known to be troubled before.

Among the several scientific societies which took up this problem was the Academy of Natural Sciences of Philadelphia. They reached the conclusion that the cause of the trouble was principally magnesium carbonate. Many of the recent writers mention that the efflorescence was supposed to be nitre or saltpeter, evidently because it resembled the deposit which appears on stable walls which have manure and other refuse piled against them. Seger seems to have been the earliest of the ceramists to have studied this problem and he demonstrated that the efflorescence is not saltpeter but rather, that it is generally sulfate of the alkalies or alkaline earths. Seger was followed by several other German investigators among whom Hans Guenther seems to stand foremost. Guenther laid particular emphasis on the role that pyrite plays as well as on the reactions that take place between the salts in the

brick and mortar. In our own country, Dr. Otto Gerlach clearly stated the possible reaction of the lime in the brick with the sulphur in the kiln gases that causes the formation of soluble sulphates.

In spite of this work that has been done, the entire cause and prevention has not been found. Efflorescence is as abundant as ever and can be found on new and old buildings alike. What has been done, however, has been a great step in advance, and by far the greater part of the unsightly stains on our buildings can be done away with if brick manufacturers and builders take the precautions already determined. Each investigator has laid particular emphasis on the particular cause he has been investigating, leaving the impression that it was the cause of all efflorescence. The fact is, there are a number of causes for the trouble, and a number of precautions to take. It is the purpose of this paper to gather together as far as possible all of the causes and means of prevention known to the writer in the hope that it may aid those who are endeavoring to overcome these unsightly stains on our brick.

Effect of Efflorescence.

It has been stated that the crystallization of salts on the surface of brick would have the same distintegrating effect as the formation of the ice crystals and cause the brick to weather so much more rapidly.[1]

On the other hand, it has been suggested that efflorescence is of benefit to the brick when it is burned because it concentrates the fluxing material, calcium, etc., near the surface of the brick. It was observed that the whitewashed bricks were the better vitrified. This is, however, an open question.

While efflorescence may or may not harm the brick in a mechanical way, it certainly does harm its appearance, and means an actual monetary loss when the appearance of the brick is part of its intrinsic value as in a face brick.

[1] (Seger, p. 372, Coll. Writ.)

Kinds of Efflorescence.

For convenience in discussing the sources and causes of efflorescence it is best to divide it into two classes, first, that which appears on the brick in the kiln or kiln white, and, second, that which appears afterwards or wall white. The kiln white is burned into and is a part of the brick, while the wall white is powdery and can be rubbed off. Kiln white is often subdivided into dryer white, or that which originates in the dryer, and kiln white, or that which originates in the kiln. While this distinction is often convenient in assigning the cause of a whitewash on the brick, yet it is often impossible to distinguish between the two without experimenting. In general, however, dryer white is almost always brought to the surface of the brick through the evaporation of the water and so appears in small pimply crystals, while the kiln white is most often caused by the reaction of the kiln gases and the lime in the brick and appears as fluffy clusters. This is not a sure means of distinguishing the kiln and dryer whites, as kiln white may also come from evaporaing water, and the dryer white may also be formed, in case of a waste heat dryer, by the reaction between the sulphur in gases and the lime in the clay. For the purposes of this paper I shall not distinguish between kiln and dryer white, as they are identical in origin and composition.

Composition of kiln white. Analyses of kiln white show it to be almost entirely calcium sulphate with small amounts of magnesium and alkaline sulphates and occasionally alum.

In order to form some idea of the relative power of the various salts to cause efflorescence a series of trials was made containing 0.5 gram each of sulphates of calcium, magnesium, and aluminum, the carbonates of calcium and sodium, and the chloride of sodium. These salts were added to 100 grms. of clay that had been previously washed thoroughly, the mass formed into brickettes, and burned under oxidizing conditions. The sulphates caused by far

the greater amount of efflorescence, the alum coating the trial entirely, the others covering the sides. The carbonates gave a thin coating of efflorescence, the sodium much the heavier of the two, and the sodium chloride simply discolored the trial, making it a little darker. From this it was seen that the sulphates were the most dangerous, but that any soluble salt is liable to cause trouble.

Source of kiln white. The sources of the kiln white salts may be said to be in the clay, in the water used in manufacture, or in the kiln gases, or perhaps in many cases all three of the sources named.

Efflorescence from the Clay.

Practically all brick clays contain or have contained sulphur in the form of iron pyrites. When the clay is exposed to the action of the air and its weathering influence, which action extends to the permanent water line, iron sulphide or pyrite oxidizes to iron sulphate.[1]

$$FeS_2 + 6O = FeSO_4 + SO_2 \quad \text{or}$$
$$FeS_2 + 3O + H_2O = FeSO_4 + H_2S$$

The iron sulphate alters with the further addition of water and oxygen to limonite, setting free the sulphur as sulphuric acid.

$$FeSO_4 + 2O + 7H_2O = 2Fe_2O_3 : 3H_2O + 4H_2SO_4$$

This sulphuric acid then enters into solution and reacts with the calcium, magnesium, aluminum, and other bases originally in the form of carbonates, silicates and chlorides, and forms sulphates as gypsum, alum, etc.

Again, the iron sulphate may react directly with the calcium carbonate, which is nearly always present, and form iron carbonate and gypsum.

$$FeSO_4 + CaCO_3 = CaSO_4 + FeCO_3$$

As the iron in an unoxidized clay is usually in the

[1] (Van Hise, Metamorphism, p. 214.)

form of either the sulphide or carbonate, and since gypsum is also a common constituent, the reaction between the sulphate of iron and carbonate of lime is probably more common than that of mere oxidation and hydration. Both reactions are, however, initially oxidation. From the foregoing it will be readily seen that the amount of whitewashing sulphates formed in a clay depends directly upon the extent to which the clay has been exposed to oxidizing influences. The oxidizing zone in the earth's surface extends down to the permanent water level. In this zone the process of oxidation is at its maximum and consequently the changes from the insoluble sulphides to soluble sulphates takes place here most rapidly. The sulphates, once formed, are soluble and will be removed by solution by the water percolating through the clay. As the clays are, as a rule, very compact and impervious, the water circulates through them very slowly. Consequently until the clay has been opened up by the action of frost and the roots of vegetation and made more pervious, the sulphates are not removed to any appreciable extent.

When soluble sulphates are present in the clay they appear on the surface of the green brick as it is drying. They may be concealed, in fact generally are, by the similarity of their color and that of the brick, but as the brick is burned the sulphates stand out as white specks on a darker background and the whitewash is brought out apparently in the kiln. Since the evaporation of the water contained in the green brick can only take place at the surface the water of the interior must come to the surface through the action of capillarity. The soluble salts are brought out in solution by the water and the water evaporating leaves the salts concentrated on the surface. Perhaps I can make this clearer by an actual case. A clay whitewashed and by experiment it was found that the trouble lay in the soluble salts of the clay. Analyses of the clay showed 0.75% sulphur trioxide, of which 8.92%, or 0.065%, in terms of the clay, was soluble. Analysis of the face of the dried brick gave 1.30% of sulphur trioxide, of

which 40.77%, or 0.56% in terms of the clay, was soluble. The gain in sulphur by the face of the brick will be readily seen to be entirely of the soluble form. In other words the soluble salts had been collected on the face of the brick by the process of drying. It is also interesting to note the very small amount of sulphur trioxide, only 0.65%, about 1.95 gram, or 0.07 of an ounce per brick that it takes to cause decided efflorescence.

As before stated, nearly all the shales and fire clays contain iron pyrites. That part of it which escapes the action of the weather enters into the brick in its original form. Although it does not cause either kiln or dryer white, it is a very large source of the wall white and it is simplest to consider it at this point. Pyrite is peculiar in the fact that it will part with one molecule of its sulphur quite readily at the comparatively low heat of 400° C., but holds tenaciously to the other until at least 900° C. In fact, there seems to be good reason to believe that it is not driven off at all except under good oxidizing conditions.[1]

The first molecule of sulphur, however, is set free at a time when there is an abundance of water and oxygen in the kiln gases, and as it passes the lime and magnesium carbonates in the clay it combines with them to form sulphates. These, once formed, are not decomposable under ordinary conditions and remain unnoticed in the brick until they are laid in the wall. Then, due to the leaching action of the rains and the water passing through the wall from the water pipes, gutters, and foundation, they appear as efflorescence.

Efflorescence from kiln gases. The sulphates in the clay are not the only cause of whitewash, however. Calcium carbonate is nearly always present in the clay, often in large quantities, and occasionally magnesium. As these are comparatively insoluble, they are not carried to the face of the brick to any extent during dryness and consequently do not form a large part of the kiln white. If,

[1](Orton. Role played by iron in the burning of clay wares. Transaction Cer. Soc., Vol. 5, p. 398.)

however, they lie at the surface, especially if in the form of pebbles, they are almost certain to form kiln white by reaction with the sulphur dioxide of the kiln gases, while that which lies in the interior, reacting with the kiln gases, forms the sulphates which come out later as wall white.

Guenther was the first to prove this in a positive manner. He burned feldspar, kaolin, and marl at a red heat in a furnace with sulphurous fumes present and found that while the feldspar was unaffected, the kaolin and marl were attacked with the formation of calcium, sodium, and other sulphates. Further, with mixtures of clay and chalk the efflorescence increased with the increase of the lime.

Gerlach, in somewhat similar experiments, found that

1. In a clay containing pyrite and calcite burned in a flame free from sulphur the amount of sulphates was increased 5 times.

2. When both clay and fuel contained sulphur the increase in sulphates was 20 fold.

3. When the clay contained calcite and the fuel sulphur the increase in sulphates was 40 fold.

4. When clay and fuel were both free from pyrite, there was but slight increase.

5. When the clay contained a large amount of pyrite but no calcite, and the fuel was free from sulphur, there was but slight increase.

6. When both fuel and clay contained pyrite but no calcite, there was but a slight increase.

From these experiments it can be readily seen what an important role the calcite in the clay and the sulphur in the fuel play in the formation of the efflorescence.

The coal burned in kilns, especially bituminous coal, contains sulphur in the form of iron pyrites or marcasite, as well as free sulphur. This is generally easily seen in the coal as bright specks or seams and is commonly known as sulphur. When the coal is burned, the iron sulphide is oxidized and sulphur dioxide, a gas, results. This passes through the kiln with the other gases. Seger[1] tried

[1] (p. 216, Collected Works.)

the experiment of condensing the water vapor in the gases of a burning kiln and an analysis showed considerable amount of sulphuric acid and some hydrochloric acid. As most chlorides are quite volatile it is probable that the hydrochloric acid does not play any large part in the formation of whitewash, but passes out into the open air. The sulphuric acid, on the other hand, reacts with the carbonates and other calcium salts to form sulphates which are stable under all kiln conditions except a reducing fire. Thus it is possible that a clay that did not originally contain any sulphates could show whitewash, and in fact the work of Guenther and Gerlach has shown that this is a very fruitful cause.

It is an often observed fact that the bricks in the colder parts of the kiln show whitewash when the rest of the ware is free from it. This can be explained by the fact that the bricks in the warmer parts of the kiln begin to give up their water before the other brick have become heated. These colder brick then would condense this water vapor containing sulphuric acid from the kiln gases and absorb it. The absorbed acid acts on the lime, etc., forming sulphates which are left on the surface of the brick.

Again it is a fact that a brick set wet will whitewash. This can be explained by the absorption of the sulphurous gas by the water in the brick and as the acid will penetrate all parts of the brick through diffusion sulphates will form and be carried to the surface of the brick as it dries out. There are probably other salts, chlorides, nitrates, etc., which occur in minute quantities that contribute their share to the trouble, but they are very rarely present in large enough quantities to cut any figure.

Efflorescence from the water. The water used is generally drawn from wells or streams and always contains salts dissolved in it. These are principally calcium and magnesium carbonates, sodium sulphate and other chlorides, phosphates, and nitrates. As a rule these do not amount to more than from .02% to .05% and since there is

only approximately 800 grams of water used in each brick, this would introduce only 0.4 gram of salt, an amount entirely too small to cause trouble. If the salts rise much above 0.05%, the water may be an important factor in causing efflorescence, since the principal salts, calcium and magnesium carbonates, combine with the sulphurous fumes of the kiln gases as has been explained before.

Means of prevention. The principal causes of the kiln and dryer white lie, then, in the sulphates and carbonates of the clay, and in the sulphurous gases in the kiln. The remedies, therefore, must be applied with this in view.

The following means of prevention are suggested:

1. Use the clay before the soluble salts form, i. e., unweathered.

2. Remove the soluble salts entirely from the clay, i. e., weather it thoroughly, thus causing the washing out of the salt.

3. Transform the soluble salts to a harmless form by precipitation.

4. Prevent the concentration of the salts on the surface of the brick by rapid firing.

5. Remove the whitewash in the kiln by means of a reducing flame.

6. Coat the brick with some combustible substance that will remove the whitewash as it burns off.

1. Since the sulphates in the clay nearly always result from the weathering of its pyrite, it is often possible to avoid the whitewash simply by using the clay fresh from the bank, rejecting that which has been exposed to the weather any length of time. This is only possible with clays that lie below the permanent water level. This use of the fresh clay, however, leaves the pyrite in the clay, and as has been shown, it will sooner or later come out as efflorescence on the walls. While the manufacturer is thus enabled to produce a clean brick, he is simply passing the trouble on to the user of his wares.

2. Since the whitewashing salts are all soluble or can be rendered so by weathering, it is possible to remove them

entirely by exposing the clay to the action of the air, rain and frost as long as is necessary. As the action is slow and will not penetrate the clay unaided, the clay should be spread in thin layers and worked over occasionally. As the object is to remove the salts entirely, the ground upon which the clay is spread should slope enough to thoroughly drain the water away from the clay after it has done its work. This process not only removes the whitewashing salts, but also increases the plasticity of the clay. The process takes several months and is too expensive on that account for most brick plants.

It is possible to remove those soluble salts already formed in the clay by washing it. In using this process it must be borne in mind that the object is to remove the impurities and soluble salts and consequently a good supply of water must be at hand. In one case, at least, the water was being used over and over again until gypsum crystals of good size could be found quite plentifully in the storage tank of the washer. As in the process of weathering, the washing not only removes the salts but gives a more homogenous and better product. Its only disadvantage is the increased cost which need not be large if a good supply of water is to be had.

3. The method in most common use to transform the soluble into insoluble sulphates is to mix small amounts of barium carbonate or chloride with the clay. When either of these salts are introduced into a clay containing soluble sulphates the barium combines with the sulphur and forms barium sulphate, one of the most insoluble compounds known.

$$BaCO_3 + CaSO_4 = BaSO_4 + CaCO_3$$
$$BaCl_2 + CaSO_4 = BaSO_4 + CaCl_2$$

As the barium sulphate is very insoluble and is not decomposed during the burning the sulphur is firmly locked in the interior of the brick as long as the brick endures.

Barium carbonate is also a very insoluble compound

and must be ground finely and very thoroughly mixed with the clay to accomplish the end that is sought. A German writer[1] recommends that it be ground in a tube mill together with fine sand, which has the effect of soon reducing it to the very fine powder that is wanted. The correct amount, which necessitates a chemical analysis for its determination, is then added to the clay as it enters the pug mill. The carbonate is perfectly safe to use, as neither an excess of the barium nor the calcium carbonate formed will cause efflorescence. Its success depends on the thoroughness with which it is ground and mixed with the clay.

The chloride, on the other hand, is soluble and consequently does not need much care in grinding and mixing. As it is soluble, it is rather dangerous to use, for any excess is carried to the surface of the brick and forms there a whitewash with the sulphur in the kiln gases. Its by-product, calcium chloride, is also soluble and is liable to form whitewash in the same way. The Germans frequently use both the carbonate and chloride, adding enough of the chloride to overcome most of the whitewash and depending on the carbonate to take care of whatever whitewashing salts remain.

4. It is often possible when a clay shows a tendency to whitewash, to hold the whitewash inside of the brick by drying as quickly as possible. The mechanics of this is simple, and depends on the property of capillary tubes.

A simple experiment suggested by Dr. Lincoln of this University will make this clear to any one who will try it. If a strip of filter paper be hung with one end in a solution of potassium permanganate, as the solution ascends the paper it will soon be noticed that the water is traveling faster than the permanganate. The clear strip of the water will grow broader until the top of the paper is reached. This is due to the fact that the wet paper has a stronger attraction for the salt than the water, and consequently the salt cannot travel until enough of it is attached to the fibres of the paper to allow the water to

[1] (Brick, Vol. 9, p. 32.)

draw the salt higher. Just why this should be is not known, but it is the phenomenon chemists have named adsorption. So when the brick is dried quickly the water is evaporated before the salt reaches the surface in sufficient quantities to cause trouble. When the clay will not permit of rapid drying this method cannot be used.

5. The sulphates once formed cannot be decomposed or removed in an oxidizing flame at any temperature ordinarily reached in the kiln. In a reducing flame the sulphates are reduced at temperatures of 1000° C. to sulphides. The bases enter into combination with the silicates of the brick, while the sulphur is driven off with the gases. By use of this principle it is possible to drive off the whitewash by finishing the burn under reducing conditions. This has the disadvantage of darkening the color of the brick and also causing the slagging of the iron into a ferrous silicate, thus starting fusion prematurely.

6. A method in vogue in Germany is to coat the brick on the face, as they leave the machine, with coal tar or wheat flour. As this burns away it has a strong reducing action and removes the whitewash as just explained. From all reports I have seen of the method, it seems to give good results. I do not know of its having been tried in this country, however.

Summary.

To sum up, kiln and dryer white can be avoided by using only fresh clay, by weathering and washing it, by the use of barium, by quick drying, by alternately reducing and oxidizing when finishing the burn; or by coating the face of the brick with coal tar or wheat flour.

Wall White.

The composition of wall white is somewhat more varied than kiln white and several additional factors enter into its productioin. As examples of the different modes of occurrence and composition of the efflorescence I will mention a few samples that were collected from some of the buildings of the University of Illinois.

Building.	Brick.	Mortar.	Position, form, color, etc.	Composition.
1. Engineering	Yellow pressed	Lime	Efflorescence noticeable on all of the brick, not on the mortar. Especially thick on a column that had water pipes behind it, also bad patches where radiators were near wall. Also on sand stone in first story near entrance which projects from the building	$MgSO_4$, with traces of Ca and Cl.
2. Agricultura[1]	Yellow pressed	Lime	On brick wainscoting in hall. Sink just back of the wall. Efflorescence white in a patch just below the level of the sink	$MgSO_4$ and trace of calcium.
3. Agricultural	Bedford lime stone	Lime	White efflorescence on first story on the north wall of creamery	$CaSO_4$ and $NaCO_3$.
4. Wood shop	Red pressed	Lime	White efflorescence especially bad on the north wall near cornice	$MgSO_4$ and NaCl.
5. Library	Brown sand stone	Lime colored red	White efflorescence on front of the building near cornice. Generally on or near the mortar	Not determined. Probably a sulphate.
6. Pier back of Engineering Building	Red, common	Neat cement	White efflorescence on both the brick and mortar, near the top	$CaSO_4$, trace of CO_2.
7. Pier back of Engineering Building.	Red, common	Lime	White efflorescence on brick and mortar near the top	$MgSO_4$, trace CO_2 and Cl.

Building.	Brick.	Mortar.	Position, form, color, etc.	Composition.
8. Pumping Station	Yellow pressed	Lime	White efflorescence on and near mortar, about two feet from the ground	$CaSO_4$, trace of CO_2.
9. Hydraulic Laboratory	Yellow pressed	Lime	White efflorescence on the stone trimmings of basement	$MgSO_4$, $CaSO_4$.
10. Hydraulic Laboratory	Pressed	Lime	White efflorescence on the north wall, with large testing tank behind it	$HNaCO_3$, Na_2SO_4.
11. Hydraulic Laboratory	Pressed	Lime	Same situation as above. Greenish efflorescence	$MgSO_4$, trace Ca.
12. Electrical Laboratory	Yellow pressed	Lime	Drab efflorescence on wall to basement entrance	$CaSO_4$, trace of Mg.

From the above it will be readily seen that the sulphates of magnesium and calcium are the most constant constituents of the efflorescence, although sodium and potassium may be present. The carbonates are also a fairly constant part of the whitewash and occasionally chlorides may be present. In No. 10 the principal salt of efflorescence was found to be sodium bicarbonate. This particular efflorescence was peculiar in that it deliquesced and became syrupy after it was corked up in the specimen tube. Sodium and potassium are probably more frequently present than these results would indicate, as with the means at hand it was not possible to detect small amounts of these substances with certainty. In fact, analyses made here a few years ago by Steinmeyer, thesis 1902, Chemical Department, showed them to be present in all the specimens of efflorescence examined at that time.

All of the efflorescences are not white, but are discolored more or less by the soot that finds lodgment in them. Some are green, as was No. 11, but the amount of the efflorescence that could be collected was too small to determine the coloring matter. Seger states that some green efflorescences he examined were colored with salts of vanadium. Other writers have ascribed the color to iron and chromium. Unfortunately not enough of the green was found for examination and nothing further can be added at this time. It is certain if vanadium is the cause it does not exist in the clay in a soluble form before being burned, as both Seger and Gerlach were unable to find it after lixiviating large amounts of clay. The green efflorescence seems to occur only on the lighter brick and has not been observed on the red brick so far. Much of the greenish scum appearing on the walls especially in damp places is due to a minute plant and is not an efflorescence at all.

Means of determination. It was thought that it might be possible to determine the main constituents of any efflorescence by observing the forms of the crystallized salts as they appeared on the wall and with this end in

view a number of briquettes were made of a surface clay that had been thoroughly washed to remove any soluble salts that might be present. After being burned, these were then placed in 0.5% solutions of the sulphates of calcium, magnesium, iron, sodium, and potassium, the carbonates of sodium and potassium, and sodium bicarbonate. The briquettes were left with their tops exposed to the air and after the efflorescence had appeared they were taken out of the solution and dried. As before, the sulphates took the lead, especially the sodium, iron and magnesium sulphates, although the sodium carbonates were not far behind. One surprising result was that the potassium and sodium salts did not effloresce. Consequently, the small amount of the salt that came through remained in two or three small white knobs. The main result was, however, negative, for as soon as the salts crystallized on the surface they effloresced, and all crystalline form was lost.

Again it was thought that it might be possible to dissolve a little of the efflorescence in distilled water and allow it to crystallize by the evaporation of the water. Then, since each salt should crystallize by itself, the composition of the efflorescence could be determined by examination of the crystals. With the pure solutions of the salts this plan worked very well, but on mixing them, as would be the case in the efflorescences, it was found that the salts as a rule no longer retained their characteristic forms and the plan had to be abandoned. The reason for this seemed to be the fact that the several crystals formed were so superimposed as to hide their shape.

Occurrence of wall white. Referring again to the efflorescences described, with reference to the places where they are most apt to occur, it will be seen that they only appear as a rule where there is excessive moisture such as near the cornices, near the ground where the water in the soil passes up through the foundation and evaporates and where the wall carries or has water pipes or radiators near it. In other words, the efflorescence is not trouble-

some except where there is plenty of water to bring it out. The rain undoubtedly has something to do with the appearance of the efflorescence on the walls, for it is a well known fact that a dry brick will absorb water very quickly. So with every rain storm there is a certain amount of water that penetrates the brick and brings out the soluble salts and deposits them on the surface when it evaporates again. As the salts, calcium sulphate excepted, are very soluble, the rain washes off what was deposited from the last rain and so the efflorescence is not large in amount at any one time, and besides, as it is evenly distributed over the wall, it is not unsightly.

At the cornices where the water of the roof is concentrated, especially if the gutters leak, the water is able to enter the wall and to travel a distance through it before it evaporates from the surface. During its passage it dissolves the soluble salts of the brick and mortar, and carries them to the outside of the wall. As the part of the wall where the salts are deposited is generally rather limited in extent the result is an ugly blotch that disfigures the building. In the same way water pipes or radiators supply the necessary water to carry the salts to the surface either through direct leakage or by condensing the moisture of the air upon them and thus keeping the wall damp. The foundation is generally in intimate contact with the soil and the water in the soil, travelling through the capillary pores of the soil and the wall, evaporates on the wall just above the ground. This again causes the salts to be gathered on the surface of the brick and again the disfiguring whitewash appears.

In every case of efflorescence I have been able to examine the blotches were caused by an excess of water produced in one of these three ways. Often on buildings not supposed to whitewash the faint even coat produced by the leaching action of the rain could be seen, showing that if care were taken to prevent the other causes, the whitewash from this cause would not be troublesome.

Pressed brick are especially subject to this disfigurement, since their smooth surface shows every spot. It has often been observed that sand-molded brick did not show efflorescence, while pressed brick made of the same clay would. This can be explained only by the difference in the structure of the faces of the two bricks. The rough surface conceals the little pimples raised by the salts and besides retains more dust and dirt with which to color the efflorescence, while on the smooth surface of the pressed brick the salts stick out obtrusively and retain their natural whiteness, since the dust and soot that colors them must come from the air.

Again the law of adsorption explained in regard to the drying of the brick holds good here. The pressed brick have a dense surface and fine pores, necessitating slow evaporation, while the sand-molded brick are more porous and water can evaporate from them more rapidly. In consequence the greater amount of efflorescence is brought to the surface of the pressed brick.

The sources of the wall efflorescence lie in the brick, the mortar, or in materials brought in contact with them as water, soot, or refuse.

As has been stated in explaining kiln white, practically the only soluble salts left in the brick are the sulphates of calcium and magnesium. These may have been originally in the clay or may have been formed in the brick during the process of manufacture through the reaction of the pyrite in the clay and coal with the carbonates in the clay. The manner in which these salts affect efflorescences differs.

Of the two, magnesium is much the more soluble and, as we have seen, effloresces much more freely. On the other hand the calcium sulphate once formed on the surface of the wall is much more difficult to remove. Again, while the magnesium generally effloresces unaltered, the calcium is more apt to react with the carbonates of magnesium, sodium, and potassium brought into the brick by the water from the mortar, forming calcium carbonate which is quite

insoluble and remains in the interior of the brick, while the sulphates of magnesium and sodium formed by this reaction, effloresce. This was well illustrated in the first case mentioned, where it was possible to pick bits of calcium sulphate from the face of the brick with a knife, while the efflorescence consisted almost entirely of magnesium sulphate.

The lime in the mortar furnishes the sulphates, carbonates, and chlorides of calcium, magnesium, sodium, and potassium. The sulphates are formed during the burning of the lime by the reaction of sulphurous gases formed by the burning coal with calcium, etc., of the limestone. This reaction is the same as was worked out by Guenther and Gerlach in the brick as a cause of kiln white, but as far as I know has not been mentioned as a possible cause of the wall whites. Such samples of lime and mortar as were at hand were found to contain considerable soluble sulphates and it seems possible that this is one of the most fruitful causes of the wall white. Surely it offers an explanation for many cases of efflorescence that were due to the mortar, but which was difficult to prove because the sulphate came from a medium which was principally composed of carbonates.

The sand and the water used in the mixing of the mortar may, under exceptional circumstances, be responsible for efflorescence, but as the sand used has generally been washed over and over again by the streams and circulating earth water, it is not reasonable to suppose that any amount of soluble material remains. Only in some situations where water circulating through the bed of sand is charged with material in solution can there be any deposited in it. Again the amount of salts in the water used in the mortar is so small, as a rule, it is hardly possible to believe it could cause any amount of efflorescence.

Other things added, such as coloring matter, salt, are very often responsible for the trouble. The oxide of iron generally used to color the mortar red is made by heating iron sulphate and generally all of the sulphate is not

decomposed. This reacts with the lime to form soluble sulphates and these in turn effloresce. This particular case was well illustrated by example No. 5, where the stone is a very porous silicious sandstone laid in red mortar, the efflorescence indicating its origin by appearing on or near the mortar.

Again, sodium chloride, or common salt, is added to the mortar in winter time to keep it from freezing before it sets. This salt comes out on the surface of the brick as soon as it has the water to carry it and appears as efflorescence. This was illustrated by example No. 4. An analysis of this efflorescence showed it to consist of more than 80 per cent. of salt.

Besides by the brick and the mortar, efflorescence is often caused by substances in contact with the brick. The efflorescence of brick stacked in stock piles is often caused by the cinders upon which they are stacked. The cinders contain sulphates from the coal from which they were formed and the water of the ground seeps up through them and through the brick evaporating from the faces of the brick and leaving the salts behind. Manure thrown against the wall will cause efflorescence through the nitrates and other soluble salts it contains. This is abundantly illustrated on stable walls and was first noticed there, the nitre found giving its name to all efflorescences. The soil contains nitrates especially where there is abundant vegetation and this occasionally enters the wall to appear higher up.

Benfy[1] explains the appearance of an efflorescence on the walls of buildings in Chicago by the leaching out of the sulphates of the soot, adhering to the walls by the rain which then entered the brick and evaporating, left the efflorescence behind, the soot having been washed off in the meantime.

If the water seeping through the wall has much material in solution, it is possible it would cause efflorescence on evaporation.

[1](Brick 1895, p. 358.)

As will be seen from the above, the causes of wall efflorescence are numerous, and one, at least, is omnipresent, the sulphates in the lime. If this is the case, why is it that every brick building does not show efflorescence? The answer is clear. No building can have efflorescence unless there is a supply of water to bring it out. The rains can do no more than bring out a faint even coat that is washed off by the succeeding rain. This is not a disagreeable thing and the efflorescence only becomes a nuisance when it is collected in blotches. What, then, is the remedy?

Make the walls as impervious as possible. Use well burned brick, lay a drain around the foundation and coat the foundation with a good waterproof paint before the ditch is filled in; likewise water-proof the walls and flues that convey water, or steam pipes. Take care that the cornice and roof is watertight. Attention to these simple things during the erection of a building will mean a clean wall and a much improved appearance.

After the building is finished, if the efflorescence comes out, there are only a few things that can be done. The walls may be painted which conceals the brick as well as the efflorescence and is liable to peel off in the damp spots. The walls may be treated with paraffine or linseed oil, which will darken the brick but not conceal them entirely. Then, as before, all source of water supply to this wall must be stopped if possible. In that way alone is there any hope of success for the present.

I wish to acknowledge here the helpful suggestions I have received from the various members of the faculty of the University of Illinois, and especially from Mr. Purdy, who has aided me throughout the preparation of this paper with kindly criticism and suggestions.

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DISCUSSION ON PRODUCER GAS AND ITS APPLICATION IN CERAMIC WORK.

Note by the Editor.

Mr. Samuel S. Wyer, M. E., of Columbus, Ohio, a specialist of high standing in gas engineering, accepted the invitation of the Secretary to be present at the meeting, and on Tuesday evening gave a lecture on the above subject. This lecture was illustrated by about 50 views, charts and diagrams, the whole making a most complete and instructive presentation of the subject. At the close of his lecture, Mr. Wyer very kindly threw the whole subject open for questions and debate, when the following discussion took place:

DISCUSSION.

Mr. Parker: Can a suction gas producer with gas engine replace a steam power plant, furnishing heat to the buildings from the exhaust of the engine, and accomplish the same results with a greater saving of fuel?

Mr. Wyer: It can very easily replace the steam boilers and steam engine for furnishing the power and will use very much less coal and water. The exhaust gases and cylinder water, or an auxiliary gas-fired boiler may be used to furnish the heat for the buildings. Each individual problem, however, must receive special attention.

Mr. Gorsline: Will gas producer builders give guarantees?

Mr. Wyer: Yes; if they are good gas producer builders. I know several cases where the company will guarantee an economy of one pound of coal per horse power per hour.

Mr. Gorsline: Then it would be very simple for ceramic people to use the producer gas.

Mr. Wheeler: How large are the gas engines in actual use in this country, and is there any trouble from the explosion being so severe as to crack the cylinder?

Mr. Wyer: 2,000 h. p. is the largest size I know of giving satisfactory results at the present time.

Mr. Wheeler: How many cylinders?

Mr. Wyer: Two, double acting, giving the effect of four cylinders.

Mr. Wheeler: They have been made to 5,000 h. p. abroad. Have they any trouble there?

Mr. Wyer: No; simply due to the fact that the gas engine practice is better there than here.

Mr. Wheeler: For a 1,000 h. p. plant, what would be the approximate relation of cost of gas against steam, both high grade plants?

Mr. Wyer: About the same.

Mr. Wheeler: What is the largest gas producer that has been built?

Mr. Wyer: One thousand h. p.

Mr. Wheeler: Would you dare operate a power plant with bituminous coal:

Mr. Wyer: Yes, if you get rid of the tar. There are several such plants in successful operation now. Of course, there are a number of producers which do not get rid of the tar, and the elimination of the tar is the main problem in the use of soft coal.

Mr. Wheeler: Is that tar of much value as a by-product?

Mr. Wyer: Not in small plants, because of the trouble in getting a market for it. It is better to use a producer that breaks up the tar rather than separate it mechanically. In that way you eliminate the difficulty of obtaining a market for the tar and save the heat loss represented by the carbon in the tar.

Mr. Wheeler: Does your estimate for the cost of a 1,000 h. p. plant include a holder?

Mr. Wyer: Yes. If you use a suction gas producer you will not use a holder, though none of that capacity have been built in this country to my knowledge. They have been used successfully abroad.

Mr. Ogden: If I understand correctly, with the suction gas producer you use no steam?

Mr. Wyer: Steam is used; but the steam is drawn in with the air.

Mr. Ogden: But you don't use as much of it?

Mr. Wyer: Yes, you want to use as much of it as

you can. The limited time I had prevented me from going into the details of that phase of the subject. Practically all the producers in the market have no means to secure accurate regulation of the steam and the gas taken out. Inasmuch as the amount of gas you are making varies, you should also vary the amount of steam to get effective results in the producer. You always should endeavor to use a maximum amount of steam in making producer gas. A number of builders in this country are using a smaller amount of steam than should be used for effective work. There are, however, several producers using a device which regulates the amount of steam in accordance with the amount of gas made in the producer.

Mr. Ogden: In firing kilns the supply of gas would remain constant for several hours at a time. In that case, the blast or pressure producer would be as effective as the suction producer?

Mr. Wyer: Of course, from the very nature of the case, you could not use a suction producer in connection with a kiln.

Mr. Watts: I would like to ask whether you would find difficulty in reaching the highest temperatures in ordinary pottery firing by means of producer gas?

Mr. Wyer: I could not say as to that; but I can see no reason why there should be any difficulty if you use rational means for burning; if you preheat the air and use the gas at a high temperature.

Mr. Watts: In installing a plant of this sort, would you propose passing a large pipe around over the hub of the kiln, as in the case of natural gas, and introduce it into the top of the fire holes, or would it be necessary to put it below the level of the floor and bring it in below?

Mr. Wyer: It would always be better to keep the pipe covered so as to keep your radiation low, if you are using a hot gas. Producer gas, having such low heating value per cubic foot, necessitates pipes five or six times as large to convey the same heat units as in natural gas.

Mr. Watts: Would it be necessary to make a great

change in the replacing of coal or natural gas fuel by producer gas fuel, in the kiln itself?

Mr. Wyer: There is that disadvantage. If you wish to get effective results you will have to so arrange your plant so that all these factors will receive consideration. If you should attempt to use producer gas in the same burner in which you are now using natural gas, you will get into trouble, because the ports are not large enough.

Mr. Watts: The plant I have in mind has, or will have in a few weeks, eight kilns in two rows of four each, the rows about fifty feet apart. Another bunch of four kilns is located probably 150 feet from this row. Would it be advisable to put three or four small producers there, or one large producer at one central point, where it would be necessary to go, say, a distance of 200 feet to a kiln?

Mr. Wyer: It would be possible but not desirable. It would be better to put one producer with each group of kilns.

Mr. Watts: That would mean carrying the gas approximately 180 feet, because you cannot get kilns very much less than 45 feet from centers. I think you would find pretty nearly all kilns in this country located in rows, which would mean that you must locate a producer centrally with the row of kilns. You could not locate it at one end or the other. Am I right?

Mr. Wyer: I am not familiar with all your conditions, but the prime object would be to get it close to the kiln to cut down the heat loss. There may be certain structural conditions which will not permit that. In that case you would have to stand for that loss.

Mr. Watts: Have you considered the feasibility of using the waste gases from the kiln to maintain your producer gas at a high temperature in entering the kiln? Of course, there would be loss in the early part of the burn before the return flue became heated or before you had the regenerating system established; but after that, would it not be practical to have the one flue inside the other

and in that way enable you to carry the gas quite a distance.

Mr. Wyer: That would bring in the proposition of putting in a regenerative furnace, as in the old Siemens process. Of course, a scheme like that would mean a saving of heat, but it is a question whether the cost of maintenance would pay for it.

Mr. Watts: Am I right in my impression that this system of using producer gas would practically eliminate the smoke nuisance?

Mr. Wyer: It will. You can have perfect combustion. On one plant where they were using producer gas, I recently watched quite a long time and could not notice a particle of smoke.

Mr. Watts: Would it be practicable to operate a producer on, say, a series of four kilns, operatng four producers for a plant of sixteen kilns?

Mr. Wyer: That would be better than one producer for each kiln.

Mr. Watts: Would not the cost of operating those four producers more than counterbalance the loss you would have in operating one large producer?

Mr. Wyer: It might not be feasible to operate one large enough for the sixteen kilns.

Mr. Watts: Those sixteen kilns would not be operating all of the time, but each kiln would probably be running forty out of ninety-six hours. The time of cooling, setting, and drawing, must be deducted; so you would have one producer actually operating, perhaps, three kilns all the time. Even then in the early part of each burn it would be consuming probably only about fifteen per cent. of what it would consume at the finish of the burn.

Mr. Wyer: It would be easy to adjust the amount of gas going from the producer to take care of the temperature you wish to have in the kiln. It is absolutely impossible to make a general statement which would cover all cases. If you were building a new plant of unit kilns, it would be easy to arrange the kilns so as to use

one producer for four or six kilns. Then use an auto-feeding apparatus on the producer, using mechanical apparatus to carry the coal into the storage hopper, and you will reduce the handling of the coal to practically zero.

Mr. Watts: The plant I have reference to is so arranged that the coal all comes in from above, and would come in about on a level with the top of the producer, so it would be where it would be wanted, in the first place. But I would hesitate to arrange a set of kilns in such a way as to locate the producer to greatest advantage, unless that same arrangement would be advantageous in case the producer were taken out. In case it would not prove so effective as hoped for, the kilns ought to be in such position as to be handled satisfactorily otherwise. The location of kilns in rows, as brick and many pottery manufacturers now have them, has been found the most advantageous plan for handling the ware; and there would have to be pretty thorough proof of the saving to be gained by using producer gas to persuade manufacturers to locate kilns in any other way. I am in the market for anything in the gas producer line, other things being equal, which will eliminate the smoke nuisance which is getting to be quite a serious proposition with us. For this reason I am much interested in the gas producer proposition. My idea in asking these questions is to bring out, if possible, any difficulty we might get into by putting in a producer to prove whether it might be satisfactory or not. A number of members have discussed the matter and have spoken of installing one producer in order to learn what it will do. That seems to me the best way to prove what can be done with producer gas in this connection.

Mr. Orton: It does not seem to me we are getting at the fundamental point in this discussion so far. The point we want to know is, where the economy is coming in, or what are the objections or difficulties in the application of producer gas to the burning of clay wares, as

most clay wares are burned, viz., in periodic kilns. I see some gentlemen here who have been bombarding me with queries along this line, before I knew Mr. Wyer was to speak on this subject. I have always taken the ground that I could see no great likelihood of economy from the use of producer gas in the burning of clay ware, and my objection to the use of producer gas for the periodic kiln was that producer gas, being a gas of low heating power per cubic foot, does not ignite well or give good combustion unless it can be served hot or mixed with pre-heated air. In starting off the burning of a periodic kiln, in the water-smoking process, it is almost invariably necessary to exercise great care in the rate at which the temperature is allowed to increase, and also it is generally necessary to remove from the kiln a large amount of water vapor which has gone in with the partially dried ware; and it is therefore necessary to dilute the gases at that stage with a considerable quantity of free air over and above that needed for combustion. All these conditions are inimical to the advantageous use of producer gas. The ideal conditions under which producer gas burns are those in a metallurgical furnace, and those conditions do not maintain for all the burning period of a ceramic kiln. I can see where it might be possible to use producer gas on a continuous kiln. I cannot see even on a continuous kiln where there is liable to be any great financial saving in the use of fuel in the form of producer gas rather than in the solid form. I can see how it might be used, however, without some of the troubles which would be met in applying it to the periodic kiln. I will be thankful to Mr. Wyer if he will give us his expert opinion on this point, whether producer gas does seem to open up a promising field in its application to the periodic kiln.

Mr. Wyer: Well, only where you use the gas hot and burn the gas with pre-heated air. Under those conditions I am quite sure you can burn the ware with less

coal, less labor, and under better conditions than you can by direct firing, and have perfect combustion.

Mr. Wheeler: How much less coal in the periodic kiln?

Mr. Wyer: I could not say just what, but I should say it would be twenty-five per cent.

Mr. Wheeler: How do you arrive at that?

Mr. Wyer: Because the conditions are so much more favorable for combustion with the gas than with direct firing. In the case of one continuous kiln I was told they were able to burn the ware with one-half the amount of coal. The advantage gained in a continuous kiln with producer gas is not due entirely to the producer gas system, but to the kiln. This kiln will work better with the gas, and the gas work better with the kiln. The two are interdependent. For that reason the continuous kiln industry should grow, and a large number are replacing the periodic kilns.

Mr. Stover: I was told that a large number of ceramic factories were placing their kilns in batteries of four or six and using the waste heat in this connection, and that in a battery of six it was counted that one or two would be out of commission all the time, but they must be sufficiently close to the producer to leave out one or two for repairs, etc. It was said that it took about half the fuel.

Mr. Parker: Continuous kilns?

Mr. Stover: Yes, on the continuous principle, but not necessarily a continuous kiln. They cross through the center but are individual kilns.

Mr. Geijsbeek: The best way to apply this principle is to make each fire box a producer in itself. Mr. Wyer showed one such arrangement on the screen, where the air is pre-heated and making the producer out of the furnace. In this way you get the same results as by putting in a plant for a gas producer. You get the same benefit and eliminate the smoke. We used this system

in Colorado and never had any smoke to speak of except when the kiln was first lit.

Mr. Parker: I have one kiln in the yard fixed that way. It has about eight fire boxes, and each a gas producer. Each producer has a hopper on top and a sealed door in front, so that no primary air can get in except through the nozzle where we admit steam. No coal can go in except through the hoppers. To make it economical, we take the hot air out of a cooling kiln close by to burn the gas and thus the air meets the gas as it enters the body of the kiln. It is certainly very economical, and is very much on the order of the kiln described by Mr. Geijsbeek.

Mr. Orton: Are you able to say, Mr. Parker, how much of the economy you get in this way comes from the use of the pre-heated air and how much from the gas?

Mr. Parker: There is not any particular saving except when we use pre-heated air. In addition to that, the fire boxes are so large that we do not have to clinker until we get through. We burn up all the fuel we use, and I cannot say that there is any saving beyond that, in the kiln we employ, except when we use the pre-heated air; then there is a saving.

Mr. Ogden: I will ask if the ash or refuse you get from this producer is more nearly consumed than that in the ordinary periodic kiln?

Mr. Parker: It is entirely burned out, because it remains above the grate until we are all through.

Mr. Ogden: Have you ever had any combustible determination made on that ash?

Mr. Parker: No; I only know there is quite a difference between the producer furnaces and the other kilns. In the others we take out a great deal of unconsumed coke.

Mr. Ogden: I think very few brickmakers realize how much unburned coal is hauled out on the dump. I had two combustible determinations made on the ash

from two round, down-draft kilns. The samples from each of these kilns were taken in this manner:

I went around the kiln with a wheelbarrow at intervals of three hours for a period of forty-eight hours and collected a shovelful of refuse from each fire box, making 20 bushels of refuse. This I crushed, sampled and quartered until I had two samples of about 35 pounds each. This was sent to the laboratory, where it was further sampled down and the determination made on the samples. One showed 31.4% combustible matter, the other 34.4%. That means that one-third of the refuse was combustible. If one-fifth of the coal is refuse and one-third of the refuse is combustible, one-third of one-fifth, which is one-fifteenth of your coal is hauled out on the dump. I think it is possible to reduce this. So far as I know, the refuse from a producer carefully operated never runs more than six or eight per cent. of combustible matter.

Mr. Parker: I want to correct my statement in one particular. We do clinker once, just before we put the high heat on.

Mr. Orton: In starting off a kiln with this arrangement of yours, do you start off with the air openings all sealed?

Mr. Parker: No, we burn like in ordinary firing until we get the water smoke off the kiln.

Mr. Orton: You really only apply this gas producer then for the high temperature part of your burn?

Mr. Parker: In that particular kiln, yes.

Mr. Orton: We must consider then, that you must be equipped with this gas producer and then fire as in any other kiln up to a certain point?

Mr. Parker: Yes, in this one kiln referred to above, but we have four other kilns which do the work as continuous kilns, as they are connected in series and are arranged to permit water smoking with the products of combustion from the burning kiln.

Mr. Orton: Your fire brick do not require very extensive oxidation?

Mr. Parker: Your conjecture is likely correct.

Mr. Orton: That point is frequently overlooked in case an improved method is recommended for firing clay goods. It is often viewed simply as a question of heat evolution. It is more than that. In burning your product in the kiln, you must get rid of an enormous amount of water and in order to prevent the deposition of this water as dew, you must make some disposition in the beginning, to carry off those gases. And after you get past that point, you go through the heating up stage into the oxidation period, the object being to maintain a red heat with as large a flow of clear air as possible.

Mr. Parker: You mean a clear fire?

Mr. Orton: You must have as large a flow of pure air as possible without diluting the combustion gases below red heat.

Mr. Parker: When we admit hot air we get plenty of that, we get a great flow of hot air from the cooling kiln.

Mr. Orton: That is a separate problem, not necessarily a feature of the producer gas part. I am looking at it from this point: You cannot expect to get the greatest advantage of producer gas if in the nature of the case the kind of fire you want is a wasteful fire, viewed from the standpoint of fuel consumption. What you want is a fire with two or three hundred per cent. of air. The requirement of the average red burning clay is a large excess of air, and it is only in the latter part of the burn that you want to use anything approximating good combustion. As I understand producer gas, its chief value is in getting more perfect combustion.

Mr. Parker: Yes, and when we get through the water-smoking stage we put the heat right on.

Mr. Orton: That is the point I wanted to make. With your refractory fire-clay, you have no danger from overburning; but the average clay burner cannot do that,

he has to carry it slowly up to 900° C. before he can make any attempts to raise the heat for the finishing period.

Mr. W. B. Chapman: I have one remark to make which may be interesting to the members here. It has been said several times that producer gas could not be used to advantage unless the gas is hot and unless there is some form of pre-heating the air, That has usually been the opinion held by people who have had experience with producer gas, and until lite years it was quite true. But I know a number of places where the pre-heating arrangements have been taken out and they find it works better; and I know other instances where gas producers are in operation and no pre-heating arrangements have been used, the gas being used cold and used in much the same way as you would in ceramic kilns, with a great saving over direct coal fire. These are facts as they are and not theories. The gas is made differently, to a certain extent, from what it used to be. It was made at a temperature of 1500° coming from the producer. Now, it is made as low as 300°, so the loss by radiation is much smaller and the gas can be conveyed a long distance without losing any appreciable amount of energy. If the gas comes from the producer, hot, and passes through a line 1000 feet long and cools, it only loses 10% of its value. A gentleman here told you that you were losing perhaps more than that in your ash. With the gas producer there is practically no carbon in the ash. Although there would be some loss in radiation where the gas is passing through long flues, the loss would really be less than that which you now have by direct fire. We who have had long experience and are spending all our time in the gas producer business feel so confident that we are perfectly willing to guarantee satisfactory results or take out the apparatus.

Mr. Parker: In reply to Mr. Chapman, I wish to say that with our 4-chamber kiln with 40 foot lead of gas, we have had our gas producers operating very well, and then for some reason, say on a damp day, or when

it was raining, our gas would become cold and the flues would choke up with soot. We had trouble keeping the gas burning, whereas, if we have the gas producer against the kiln, with a green fireman who is likely to have too thin a bed of coal, no trouble could occur. On the other hand, with a long lead of gas and no pre-heated air, an experienced fireman would have a great deal of trouble and no saving would be made.

The Chair: Mr. Wyer has given us an exposition of a subject of such general interest that it has not been necessary to call for discussion on the subject. I know we could continue it with profit for quite a long time, and it is a subject in which I am especially interested and desire to hear fully discussed. The question, of course, of greatest interest to us is the use of producer gas in the burning of clay goods rather than the production of power. Those who have given any study to the subject feel that the time is coming when the gas engine will largely replace the steam engine. Probably the clay industry will be one of the last to displace the steam engine with the gas engine, because of the fact that the exhaust steam from the engine is such a convenient means for drying clay wares. One or two points in regard to the saving of fuel by the use of producer gas I will touch upon.

The question as to saving fuel in the best manner in the burning of clay wares may be answered in part by giving attention to proper combustion, a matter which I think should receive more attention. As Professor Orton says, the real basis of the saving of fuel in producer gas is in the better combustion afforded. That is probably true as a general statement in its use for most purposes. But the fact is that in brick kilns, and probably in pottery kilns also,, that there is very little loss in burning from unconsumed carbon. The analysis of the flue gases from the kilns will show very small percentages of carbon monoxide. Even though the furnace be not perfect, before the gases escape, the combustible part is largely

consumed and the loss from that is a small item as compared with the immense loss from admitting too much air. There is where the loss occurs in the brick kilns and in boiler firing. There might be a saving in the use of producer gas in that very way; not that in the producer gas there is better combustion, consuming more of the carbon in the fuel, but it is probably easier to adjust the flow of air and hold back an excess of air. If the use of producer gas would permit the holding back of an excess of air in brick kilns, it would be a great economy. But if the economy is to come from the better combustion, I do not think there would be much saving. The advice given by Mr. Wyer in the closing his address should be noted. It is a well known fact that the use of producer gas for the burning of clay wares is not an experiment. It is just being tried in this country, but it has been in use in Germany for years. In some cases I have noted that the Germans are using periodic kilns with producer gas by employing it in batteries of kilns, where the air for combustion has been pre-heated in such a manner as explained by Mr. Parker. In this connection it has been observed that the economy in the use of producer gas came from the use of waste heat for pre-heating the air for combustion, a saving in the method of using the heat rather than the method of generating the gas.

Mr. Orton: We have with us a gentleman who has not attended our sessions before, but is a member of the society — Mr. Ramsey — and I wish he would speak on the subject.

Mr. Ramsey: I think at Mount Savage we can claim to have the first gas producer plant operated in the United States. In this kiln the saving over the periodic kiln, which is about 50%, comes, as Mr. Richardson says, from the continuous principle rather than from the gas.

A continuous kiln of the Hoffman type is used, fired from the top, but in burning high grade fire brick, the coal ashes gradually choke up the flues along the floor

of kiln, and it was to overcome this difficulty that producer gas was tried and found successful.

The form of producer used is a sheet iron frame lined with fire brick, the grate bars running through. I do not know that I would recommend it very highly, although it can be improved. But there is one producer plant which I have seen in use, on the other side, the Dunnachie patent, which has been in use at the works of the Glenboig Union Fire Clay Company, Scotland, since 1880

There is a series of four kilns with the producer at one end and the chimney at the other.

I have seen quite a number of brick from this kiln at different times and they showed the action of a reducing atmosphere, which had brought the iron out on the brick.

There is also another plant in Scotland today using the by-product gas from a blast furnace about half a mile away, they have now been running some four years successfully, on sanitary pottery.

Mr. Orton: Do they pre-heat the air?

Mr. Ramsey: Now you are asking me questions I would like to know myself. I am told they are making better ware and a higher percentage of good ware than with coal firing.

Mr. Wheeler: Are they getting enough gas to run the pottery?

Mr. Ramsey: Yes, not only to run the pottery but enough to supply all requirements in and around a large iron and steel works, and still have sufficient gas going to waste to guarantee 80,000 h. p. All the blast furnaces on the other side are taking out the by-products and utilizing the gases.

Mr. Parmelee: Did they use any holder to keep the pressure?

Mr. Ramsey: Yes, they had a holder near the scrubber. The Dunnachie kilns are built in batteries of four with connecting flues to take the waste heat from one to the other, so as to have pre-heated air for the gas.

Mr. Orton: One of these kilns was put up five miles

below Portsmouth, on the Kentucky side of the river. It was operated for a few months and shut down. They tore out the gas producer features and put in fire boxes and tried to make a continuous kiln. I think the failure was not due so much to the plan of kiln as to the lack of experience of the persons who had charge of it.

Mr. Ramsey: That is the point I would make. I would like to put in a gas producer, but I would like to have some other fellow put it in first. It is difficult to get skilled labor to handle it.

Mr. Orton: The firm which put in the Kentucky kiln put it in under contract and apparently there was some pretty cheap material used. The dampers leaked and could not be gotten tight and the gas would be carried to the kiln when they did not want it. The troubles were purely mechanical, due to ignorance and inexperience in handling producer gas. I do not think this instance should militate against the system.

Mr. Ramsey: For certain ware, better products are obtained, as the coal dust is eliminated.

Mr. Orton: That would not cut much figure in fire brick.

Mr. Ramsey: No.

Mr. Parker: It certainly produces cleaner brick.

Mr. Ramsey: In burning fire brick you have to use an oxidizing atmosphere; otherwise you get spotted brick, and the market will not take such fire brick. When producer gas was first tried at Mount Savage, the producer was built at one end of the kiln, but gave considerable trouble through the flues sooting up. Later the stationary producer was taken out and a movable one tried which overcame the trouble.

Mr. Orton: Do you know of any other place where they have adopted the expedient of putting a gas producer on wheels so that it may be moved about, for this work?

Mr. Wyer: No.

Mr. Ramsey: The connection between the producer

and the top of the kiln is a short iron flue 18 inches in diameter. It was moved along as the burning proceeded in the kilns.

Mr. Wyer: Something like that worked out properly would be much better than building separate producers for each compartment, for when the brick work is once heated up you can handle it better than where it is cooled down between each period of use.

Mr. Ramsey: One trouble is the heat of the top of the producer burning out the bell.

Mr. Wyer: Judicious use of steam would eliminate that trouble.

Mr. Orton: The statement was made here that we can get producer gas of such improved quality that it will give no trouble, and will ignite without pre-heated air. What type of producer gives this kind of gas, Mr. Wyer? Is it the downdraft producer, in which the gas is sucked out through a bed of hot coals?

Mr. Wyer: The downdraft producer is certainly most likely to give gas best adapted to light at low temperatures.

Mr. Orton: In passing air or steam in at the bottom and out at the top, what kind of gas is produced?

Mr. Wyer: You have dirtier gas than when it passes down through the fire. With the amount of steam being used there, you would get trouble in certain cases.

Mr. Wheeler: The object of the steam is to increase the amount of hydrogen?

Mr. Wyer: The object of the steam is to take out the excess heat in the producer by breaking up the steam into hydrogen and carbon monoxide. Then you get the heat back again in the combustion chamber.

Mr. Wheeler: If the gas had no hydrogen would it not have an extremely low calorific value?

Mr. Wyer: Producer gas always has a low calorific value.

Mr. Wheeler: The main heat value is then the

hydrogen content? Is it practically necessary to use steam to get a proper calorific value?

Mr. Wyer: Not for the calorific value, but to get the proper gasifying conditions.

Mr. Wheeler: Has anyone attempted to use the water gas process?

Mr. Wyer: They have not been able to make it successful because it must be intermittent. That is the reason why producer gas has been able to outdistance all others on the market; it has simplicity, flexibility and continuity — all the elements most necessary to success.

Mr. Ramsey: Would it be possible where there would be a large amount of gas consumed to put up a gas producer of sufficient capacity, passing the gas through scrubbers, and introduce it directly into the periodic kiln?

Mr. Wyer: Not for the sake of economy, but for the sake of getting clean fuel for certain kinds of ware, it would be advantageous, especially if a by-product plant is put in.

Mr. Ramsey: Could it be introduced the same way as natural gas?

Mr. Wyer: Your ports would have to be larger.

Mr. Ramsey: I understand that, but would it not require pre-heated air?

Mr. Wyer: I could not say whether you could get the temperature you would want or not, without pre-heated air.

Mr. Wheeler: Would the loss of temperature in scrubbing be more than made up in the by-products?

Mr. Wyer: I could not lay down any general rules to fit all cases. Every problem must be given special study. It is entirely feasible to build a producer which will reduce the temperature to 300° as the gas leaves the producer. If you put in a by-product plant, you will not want to use the same type of system as when you pass the gas direct into the kiln. In other words, you must always adapt the producer to the conditions under which

you expect to use it. One which will give satisfactory results for one kind of work may be an absolute failure under other conditions, for another kind of work, due to the fact that the producer is not adapted to those special conditions.

Mr. Orton: Take the gas producers which have been put in lime-burning plants: There is regularly provided a stack, as part of the outfit, for burning out the flues, is there not?

Mr. Wyer: In a good many cases.

Mr. Orton: I have seen these plants put in very expensive systems for producer gas, but they provide a chimney for burning out the flues. Can you give us any idea what percentage of the coal they are throwing away in thus burning out their tar and soot?

Mr. Wyer: I cannot, because it would vary with the type of producer being used. I know of cases where they waste as high as ten per cent. in tar and soot.

Mr. Orton: The average is scarcely less than five per cent.?

Mr. Wyer: Scarcely ever less than that with the type of producer used for the kind of work in question.

The Chair: I want to say a word to correct an impression which might go out from what I said. I was speaking entirely of producer gas as a saving of fuel in the burning of clay wares. I want to be understood also as stating in connection with this, that I believe that there are many advantages in the using of producer gas in the burning of clay products and that it will have quite extensive use in certain cases, in the burning of certain clay products and certain kinds of clays. I did not mean to imply in anything I said that producer gas is not an advantageous thing to use by clay workers. In closing this discussion upon this subject at this late hour, I want to say that I think all appreciate what Mr. Wyer has done for us in coming such a distance and giving us this lecture this evening, and I trust the society will give formal expression to their sentiments.

Mr. Wheeler: I move that the thanks of the society be extended to Mr. Wyer for his very valuable and instructive lecture. It was certainly very plain and a grand treat to all of us.

Motion seconded by Mr. Parker.

Mr. Orton: I want to add my tribute to Mr. Wyer for the treat he has given us. Never before have we had a man not connected with the Society come such a long distance just to give us a lecture. He has not only made his convenience ours, but he has given us a most luminous exposition of the present status of the use of producer gas. I think his work is a classic in itself.

Motion unanimously adopted by a standing vote.

NOTE.

Mr. Ramsay sent a letter received by him from Mr. Robert Russell, Newmains, Lancashire, England to the Editor, with permission to quote the following extract. — EDITOR.

"Raw coal as you know is the fuel used in the blast furnaces of Scotland. The gases are drawn from the furnaces by three steam turbines running at about 7000 revolutions per minute through many miles of atmospheric condensers, each about 50 ft. high x 20″ diameter, which cools down the gases from about 400° F. as they leave the furnaces, to a little over atmospheric temperature, thence through washers or scrubbers to extract from them the tar and ammonia, the cold clean gas passing on to the following places:

(1) To the boilers for raising steam.

(2) To the fire brick stoves for heating the air for the blast furnaces.

(3) To stills where the water is separated out, leaving creosote oil and pitch.

(4) To the ingot mould foundry for drying purposes.

(5) To the iron foundry for drying purposes.

(6) To the steel foundry for melting the steel and for drying purposes.

(7) To the iron ore brickworks for burning iron ore bricks.

(8) To the fire clay works, three-quarters of a mile away, for burning fire bricks and fire clay sanitary ware.

The supply of gas for the fire clay works is conveyed there in 16″ diameter cast iron pipes, under a pressure of about 7 inches, water guage, where it is distributed to the various kilns, making and drying sheds and steam boiler. The pipes led into the kiln fire boxes are 4″ and 9″ in diameter.

Two kilns were at first erected to be burned on the regenerative system, but they were not a success, and are now being used in the ordinary way, viz., the gas is turned on and air is admitted through a small hole or holes in the wall directly above the gas pipe. The kiln burner has only to watch that the proportions of gas and air are such as to get complete combustion.

The time taken to burn off a kiln by gas or coal is practically the same. I regret I cannot inform you what quantity of gas is used at the fire clay works, as we have abundance of it to spare, and therefore it was not of sufficient importance for us to know, to be at the expense of a meter for measuring the quantity.

The following is an analysis of the gas:

CO_2	6.00	62.30
N	56.30	
CO	27.00	37.70
H	8.00	
CH_4	2.70	
	100.00	

The heating value of the gas is 130-134 British thermal units."